

wells tested during low flow (Table 1), and 6 of 8 wells tested during high flow, including twice in 4 of the 5 wells re-tested during high flow (Table 2). In total, sodium standards were exceeded 16 times (Tables 1 & 2). Sodium was 2.1X the standard in the sample from the spring, and 2.1X the standard in the sample from the municipal water supply (Table 1). Interestingly, sodium was only 1.6X the sodium standard in the hot water heater, and had a concentration factor of only 3.3X compared to the source well (source identity 4826) from which the hot water heater (source identity 4831) was supplied. Therefore, sodium had the lowest concentration factor of any of the regulated chemicals that were detected in the source well.

#### Non-regulated chemicals in Williamson area well water

Calcium, magnesium, potassium, and silica were present in all wells, springs, the municipal water sample, and the hot water heater tested under both low and high flow conditions (Tables 1 & 2). Calcium and magnesium were the most abundant non-regulated chemicals tested. Potassium and silica were also present in high concentrations relative to other elements.

Strontium was present in 8 of 12 wells tested during low flow conditions (Table 1), and 4 of 8 wells tested under high flow conditions (Table 2). Cobalt was detected in one well during low flow conditions (Table 1), and one well tested during high flow conditions (Table 2). Vanadium was detected in 5 wells tested during low flow conditions, in the municipal water sample, and in the hot water heater sample (Table 1). Vanadium was not detected in any of the 8 wells tested during high flow conditions (Table 2).

Of the 7 non-regulated chemicals tested, strontium and vanadium were not detected in the source well (4826) but were detected in the hot water heater (4831). Multiplication factors from source to hot water heater for the other 5 non-regulated chemicals indicated the following rates of increase: calcium=1.9X, magnesium=1.1X, potassium=1X, and silica=13.2X. Cobalt was not detected in either the source or the hot water heater. Of the non-regulated chemicals, only silica multiplied to the extent witnessed for many of the regulated chemicals.

**Table 1.** Summary of well water chemistry ( $\mu\text{g/l}$ ) during low flow conditions within 3 miles of a coal slurry impoundment in Mingo County, WV, February 25 & 26, 2004 (n.d.=non-detect, values shown in bold with borders exceed EPA limits).

**Source information (12 household wells, a spring used by many households, the municipal water supply, and a hot water heater)**

source	spring	well	well	well	well	muncpl.	well	well	well	well	well	well	well	well	heater
well depth (feet)	0	26	158	55	220		100	85	100	79	150	78	189	100	100
location in hollow	bottom	middle	head	head	middle	tap	bottom	bottom	bottom	head	bottom	bottom	middle	bottom	bottom
source water hardness	207	130	89	70	120	240	158	207	229	90	403	185	301	240	151
source identity (Map 1).	4816	4821	4818	4852	4819	4824	4802	4856	4817	4826	4844	4836	4845	4841	4831

**Regulated Chemicals (all values in  $\mu\text{g/l}$ , micrograms per liter, or parts per billion)**

	EPA stdnd.	<b>Primary (enforceable) standards</b>													
		spring	well	well	well	well	muncpl	well	well	well	well	well	well	well	heater
Arsenic	<b>10</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3	n.d. <b>150</b>
Barium	<b>2000</b>	n.d.	n.d.	700	500	400	n.d.	200	900	300	100	n.d.	100	100	<b>2400</b> <b>3000</b>
Beryllium	<b>4</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1
Cadmium	<b>5</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Chromium	<b>100</b>	7	n.d.	n.d.	n.d.	n.d.	3	6	3	n.d.	4	7	9	7	29
Lead	<b>15</b>	n.d.	n.d.	n.d.	n.d.	n.d.	<b>16</b>	6	n.d.	n.d.	<b>16</b>	<b>19</b>	<b>20</b>	<b>23</b>	<b>16</b> <b>188</b>
Selenium	<b>50</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<b>65</b>	n.d.	n.d. <b>646</b>

**Secondary (recommended) standards**

Aluminum	<b>200</b>	n.d.	10	60	n.d.	50	30	60	50	60	n.d.	n.d.	60	50	n.d.	200
Copper	<b>1300</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	53	n.d.	n.d.	n.d.	n.d.	n.d.	390
Iron	<b>300</b>	14	271	120	<b>364</b>	39	n.d.	<b>1257</b>	<b>5339</b>	<b>10553</b>	<b>473</b>	<b>1015</b>	<b>1569</b>	<b>25280</b>	<b>1221</b>	<b>557700</b>
Manganese	<b>50</b>	n.d.	n.d.	23	29	<b>52</b>	35	<b>67</b>	<b>269</b>	<b>308</b>	<b>55</b>	<b>57</b>	<b>2999</b>	<b>435</b>	<b>157</b>	<b>27260</b>
Zinc	<b>5000</b>	n.d.	64	n.d.	25	n.d.	n.d.	137	15	49	26	48	239	67	61	2118

**Lifetime health advisory**

Nickel	<b>100</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sodium	<b>20000</b>	<b>41300</b>	<b>25500</b>	<b>83700</b>	<b>23900</b>	<b>106700</b>	<b>42300</b>	<b>26300</b>	<b>29300</b>	<b>30400</b>	9500	<b>101000</b>	7600	<b>41100</b>	<b>184400</b>	<b>31200</b>

**Summary statistics**

exceedence of standards	1	1	1	2	2	2	3	3	3	3	4	4	4	5	7
best-to-worst ranking	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

**Non-regulated (N.R.) chemicals**

Calcium	<b>N.R.</b>	42000	25000	22400	17100	31500	48400	36900	53500	58000	24200	85000	52600	70700	65500	46700
Strontium	<b>N.R.</b>	1500	n.d.	930	n.d.	720	700	650	840	760	n.d.	2210	n.d.	660	2580	1210
Cobalt	<b>N.R.</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	12	n.d.	n.d.	n.d.	n.d.
Magnesium	<b>N.R.</b>	24800	16400	8100	6600	10000	28800	15900	17800	20500	7200	46400	13000	30100	18500	8200
Potassium	<b>N.R.</b>	7600	4100	3400	3400	3500	3400	3300	3900	3500	4300	8900	4000	3700	4200	4200
Silica	<b>N.R.</b>	3940	5120	7040	8000	7820	3150	7800	12020	10600	7480	4240	11150	9050	10520	98590
Vanadium	<b>N.R.</b>	n.d.	10	n.d.	35	n.d.	10	n.d.	n.d.	13	n.d.	n.d.	16	22	n.d.	91

**Table 2.** Summary of well water chemistry ( $\mu\text{g/l}$ ) during high flow conditions within 3 miles of a coal slurry impoundment in Mingo County, WV, April 16, 2004 (n.d.=non-detect, values shown in bold with borders exceed EPA limits)

source	well	well	well	well	well	well	well	well
well depth (feet)	78	85	100	189	55	220	120	n/a
location in hollow	bottom	bottom	bottom	middle	head	middle	middle	n/a
source water hardness	163.6	90.2	136.4	246.9	68.1	72	186	757.9
source identity (Map 1).	4836	n/a	4802	4845	4852	4819	n/a	n/a

**Regulated Chemicals (all values in  $\mu\text{g/l}$ , micrograms per liter, or parts per billion)**

	EPA standard	<i>Primary (enforceable) standards</i>							
		<u>well</u>	<u>well</u>	<u>well</u>	<u>well</u>	<u>well</u>	<u>well</u>	<u>well</u>	<u>well</u>
Arsenic	<b>10</b>	n.d.	8	4	8	<b>44</b>	<b>340</b>	5	n.d.
Barium	<b>2000</b>	200	500	200	400	500	500	400	n.d.
Beryllium	<b>4</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1	<b>7</b>
Cadmium	<b>5</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Chromium	<b>100</b>	6	17	4	8	2	4	18	24
Lead	<b>15</b>	10	12	10	<b>22</b>	9	n.d.	<b>110</b>	<b>30</b>
Selenium	<b>50</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

***Secondary (recommended) standards***

Aluminum	<b>200</b>	170	70	70	70	30	40	50	<b>8030</b>
Copper	<b>1300</b>	n.d.	n.d.	n.d.	131	n.d.	n.d.	758	n.d.
Iron	<b>300</b>	<b>7586</b>	<b>57588</b>	<b>2203</b>	<b>27327</b>	<b>4214</b>	<b>9701</b>	<b>25059</b>	<b>371</b>
Manganese	<b>50</b>	<b>2890</b>	<b>511</b>	<b>171</b>	<b>387</b>	<b>82</b>	<b>452</b>	<b>2953</b>	<b>4063</b>
Zinc	<b>5000</b>	1000	419	74	388	62	70	<b>5658</b>	712

***Lifetime health advisory***

Nickel	<b>100</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<b>285</b>
Sodium	<b>20000</b>	8300	15700	<b>35300</b>	<b>43200</b>	<b>30900</b>	<b>189100</b>	<b>61500</b>	<b>55800</b>

***Summary statistics***

exceedence of standards	2	2	3	4	4	4	5	7
best-to-worst ranking	1	2	3	4	5	6	7	8

**Non-regulated (N.R.) chemicals**

Calcium	<b>N.R.</b>	47300	20700	33100	60800	17300	19000	48600	99500
Strontium	<b>N.R.</b>	n.d.	n.d.	640	680	510	600	n.d.	n.d.
Cobalt	<b>N.R.</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	179
Magnesium	<b>N.R.</b>	11100	9400	13000	23100	6000	6000	15700	123700
Potassium	<b>N.R.</b>	2200	2400	2300	2300	2400	3800	2300	18300
Silica	<b>N.R.</b>	9720	11910	7050	9670	6510	5710	9440	13560
Vanadium	<b>N.R.</b>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

### **A comparison of 5 wells tested during low flow versus high flow conditions**

Five wells sampled during low flow conditions were re-sampled during high flow conditions (Table 3). The comparison included wells that ranged from 55-220 feet in depth and included sites in the head, middle, and bottom of the hollows. The comparison also included some of the better wells in terms of water quality (4852, 4819, and 4802) and some of the worst (4836 and 4845). The compared wells had consistently lower hardness during high flow events than during low flow; an apparent dilution effect. Lower hardness was the result of reduced calcium and magnesium concentrations. Iron and manganese, however, were typically greater during high flow and consistently exceeded water quality standards.

Regulated chemicals were detected 2.25X more frequently during high versus low flow events in 4 of the 5 wells compared. In the other well the detection of regulated chemicals decreased by 1, specifically selenium. The number of metals in excess of water quality standards declined by 2 in well 4836, stayed the same in 2 wells, and increased by 2 in the 2 other wells that were re-sampled. Many of the chemical concentrations measured at low flow were similar at high flow. For instance, wells with relatively low hardness at low flow also had low hardness at high flow compared to other wells. Likewise, high hardness wells had relatively high hardness under high or low flow conditions.

However, the composition of some specific elements in well water changed considerably due to flow conditions. For instance, vanadium was detected in 3 of 5 wells during low flow, but was not detected during high flow. The reverse was also apparent, for instance, with arsenic detected in only one of the 5 re-sampled wells at low flow, but 4 of 5 wells during high flow. Copper was detected only once in wells, during high flow. Selenium was detected only once in wells, during low flow.

Arsenic was not detected in well 4836 under any flow condition. Arsenic was detected in well 4845 under both flow conditions. In 3 other wells arsenic was detected only during the high flow event. In 2 of those wells, arsenic exceeded the 10 ppb standard with values of 44 and 340 ppb. Arsenic at 340 ppb was the highest level observed during this study.

Chromium was detected in 3 wells at both high and low flow, but 2 other wells only at high flow. High flow conditions resulted in lead being detected in one well where it had not previously been detected. Otherwise, chromium was consistently detected in (3 wells) or not detected (one well), regardless of flow conditions. Selenium had been detected in well 4836 during low flow, but was not detected in that well or any other well during high flow.

**Table 3.** Comparison of well water chemistry (ug/l) during low flow (base flow, February 25 & 26, 2004) versus high flow (blackwater, April 16, 2004) conditions (n.d.=non-detect, values shown in bold with borders exceed EPA limits).

source identity (Map 1).	well 4819		well 4852		well 4836		well 4845		well 4802	
well depth (feet)	220		55		78		189		100	
location in hollow	middle		head		bottom		middle		bottom	
source water hardness	120	72	70	68	185	164	301	247	158	136
flow condition	low	high	low	high	low	high	low	high	low	high

**Regulated Chemicals (all values in ug/l, micrograms per liter, or parts per billion)**

	EPA standard	<i>Primary (enforceable) standards</i>									
		low	high	low	high	low	high	low	high	low	high
Arsenic	10	n.d.	340	n.d.	44	n.d.	n.d.	3	8	n.d.	4
Barium	2000	400	500	500	500	100	200	100	400	200	200
Beryllium	4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cadmium	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Chromium	100	n.d.	4	n.d.	2	9	6	7	8	6	4
Lead	15	n.d.	n.d.	n.d.	9	20	10	23	22	6	10
Selenium	50	n.d.	n.d.	n.d.	n.d.	65	n.d.	n.d.	n.d.	n.d.	n.d.

**Secondary (recommended) standards**

Aluminum	200	50	40	n.d.	30	60	170	50	70	60	70
Copper	1300	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	131	n.d.	n.d.
Iron	300	39	9704	364	4214	1569	7586	25280	27327	1257	2203
Manganese	50	52	452	29	82	2999	2890	435	387	67	171
Zinc	5000	n.d.	70	25	62	239	1000	67	388	137	74

**Lifetime health advisory**

Nickel	100	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sodium	20000	106700	189100	23900	30900	7600	8300	41100	43200	26300	35300

**Summary statistics**

exceedence of standards	2	4	2	4	4	2	4	4	3	3
number of detects	5	8	5	9	9	8	9	10	8	9

**Non-regulated (N.R.) chemicals**

Calcium	N.R.	31500	19000	17100	17300	52600	47300	70700	60800	36900	33100
Strontium	N.R.	720	600	n.d.	510	n.d.	n.d.	660	680	650	640
Cobalt	N.R.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Magnesium	N.R.	10000	6000	6600	6000	13000	11100	30100	23100	15900	13000
Potassium	N.R.	3500	3800	3400	2400	4000	2200	3700	2300	3300	2300
Silica	N.R.	7820	5710	8000	6510	11150	9720	9050	9670	7800	7050
Vanadium	N.R.	n.d.	n.d.	35	n.d.	16	n.d.	22	n.d.	n.d.	n.d.

## **A comparison of Williamson wells with regional domestic water wells**

The results of well water sampling in the Williamson area were compared to results available from nearby domestic well water samples from southern West Virginia and Eastern Kentucky (Figures 1-5, Table 4). Two metals of greatest concern include arsenic (Figure 1) and lead (Figure 2). 2 additional metals that are of secondary concern, iron (Figure 2) and manganese (Figure 3) were also plotted because they are important indicators of coal related contamination. Sodium was also compared because it often exceeded lifetime health advisories in Williamson area wells (Figure 5). Summary statistics including sample size, percent of wells where elements were detected, and percent of samples collected that exceeded standards are shown in Table 4.

Samples for comparison in West Virginia counties were collected in 1997-1999 by the Division of Water Resources Groundwater Program and can be found in Appendix B of the Department of Environmental Protection's Biennial Report to the Legislature (WV DEP, 2002). Sample data for comparison in Kentucky counties were downloaded from the Kentucky Groundwater Data Repository (Kentucky Geological Survey, 2003). For Kentucky counties samples were selected for wells sampled 1) from 1994-2003, 2) in domestic water use designation wells only, and 3) by Kentucky Division of Water Resources or the Natural Resources Environmental Protection Council.

Arsenic concentrations in Williamson wells exceeded the primary drinking water standard in 2 of 8 wells (25%) during high flow conditions (Figure 1, Table 4). The 340 ppb in one well was the highest arsenic concentration in any of the regional wells. The next highest arsenic value was a Williamson well under high flow conditions at 44 ppb. Arsenic was detected in 75% of the Williamson wells during high flow conditions, and 8% of Williamson wells under low flow. Arsenic was not detected in any of the 12 wells sampled by WV DEP in Wyoming, McDowell, and Mingo Counties, West Virginia. Arsenic was detected in 14 of the 79 wells tested in Kentucky counties, including 13% of Pike County wells and 22% of Martin county wells. The highest concentration in Pike County wells was <2 ppb. Four Martin County wells exceeded the primary standard with values of 11-14ppb. Arsenic was not detected in any of the 11 Floyd County wells, however, we did locate a pollution monitoring well in Floyd County with an arsenic level of 172 ppb (data not included), approximately one-half the level witnessed in the exceptionally high arsenic concentration in one Williamson well.

Lead is abundant in Williamson area wells compared to other domestic wells (Figure 2, Table 4). One sample contained 110 ppb lead, the highest lead concentration in regional samples, and from a different well than the one that had the extraordinarily high concentration of arsenic. Lead was detected in 50% of low flow and 88% of high flow samples in the Williamson area. Lead was not detected in the 12 samples from the DEP Water Resources groundwater study. Lead was detected in 28% of Pike County samples, 18% of Martin County samples, and 45% of samples from Floyd County.

Lead exceeded the standard in 42% of Williamson low flow samples and 38% of Williamson high flow samples. Lead exceeded drinking water standards in 4% of Pike County, 4% of Martin County, and 9% of Floyd County domestic well water samples. Average lead concentrations in Williamson area samples greatly exceed average lead concentrations in other regional wells.

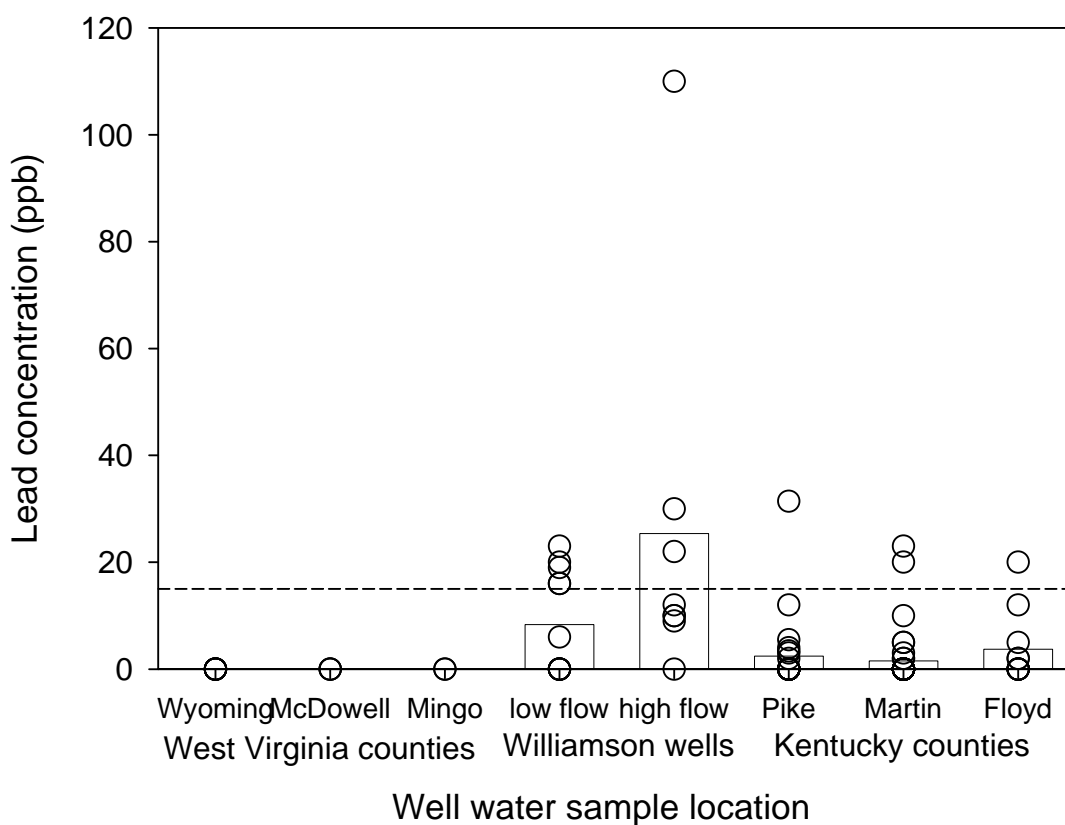
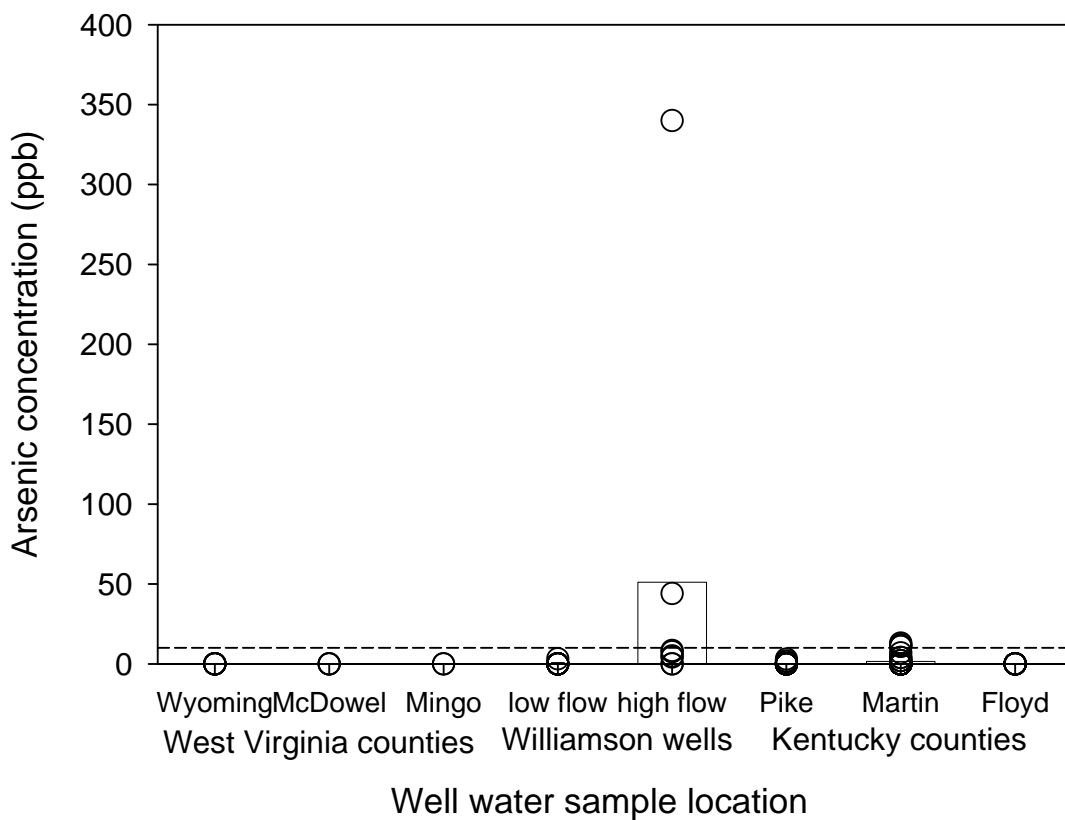
Iron (Figure 3) and manganese (Figure 4) concentrations followed patterns similar to those of arsenic and lead when comparing regional wells. Both peak and average concentrations of these elements were greater in Williamson area wells during high flow than in any other wells. During low flow, average iron concentrations in Williamson area wells were marginally less than in Pike County wells, as were peak iron concentrations. Average manganese concentrations in Williamson area wells during low flow were similar to those of Pike County and McDowell County. Both iron and manganese were detected in the vast majority of the wells in the region (Table 4).

Williamson wells at high flow and the 3 McDowell County wells exceeded standards for iron and manganese 10% of the time. One Williamson area well that was sampled at both low and high flow, 2 Williamson area wells sampled only during high flow, 4 wells in Pike County, and 1 Martin County well had extremely high concentrations of iron and manganese. These values were nearly 10-times the standard.

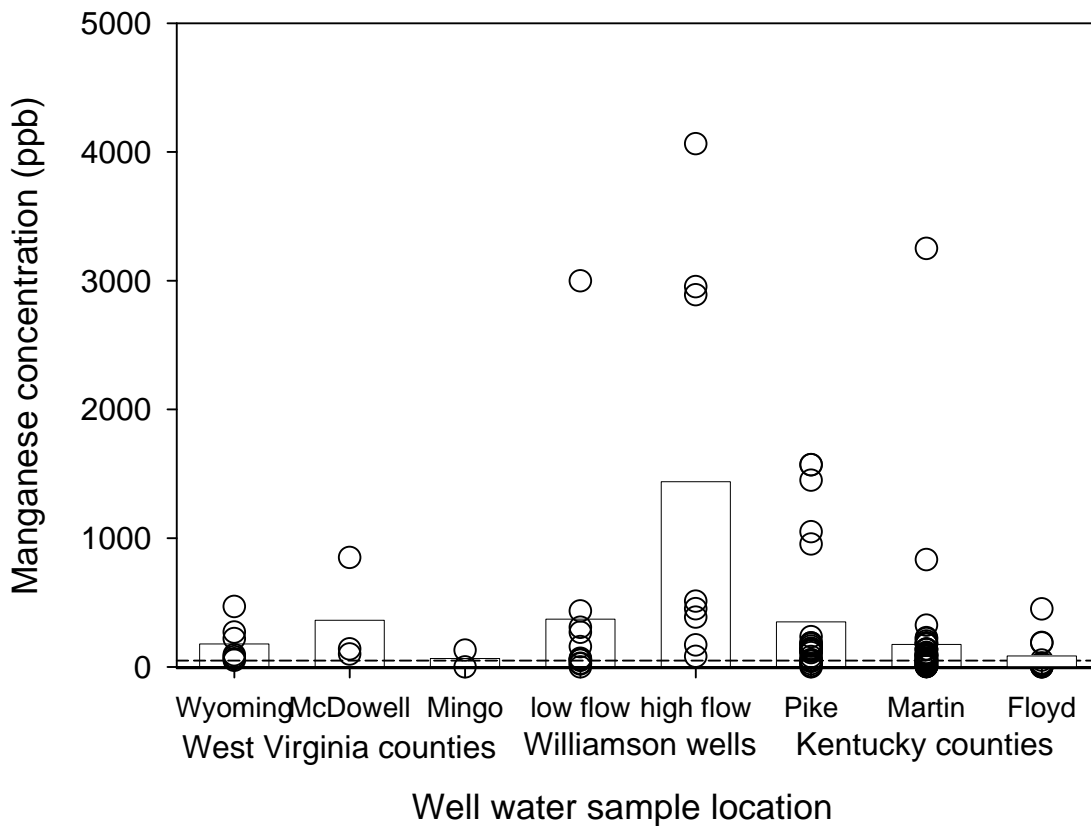
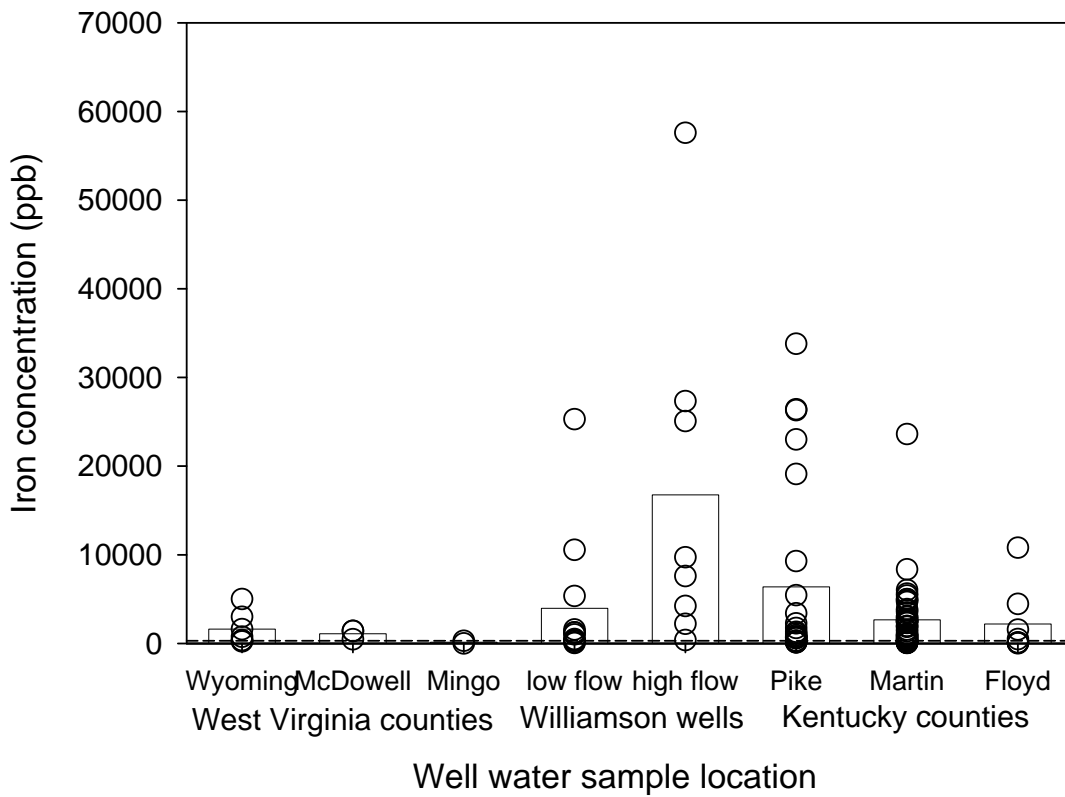
Average sodium concentrations, while way above recommended standards, show an opposite pattern to the aforementioned metals. Sodium concentrations are lower in Williamson wells than in other regional wells. This may reflect cation exchange in the presence of metals. Regardless, sodium is consistently above standard in the majority of Williamson wells. High sodium levels in the presence of high metals concentrations is an additional health effects concern for Williamson area wells.

Table 4. Summary statistics for Williamson well samples compared to other regional well samples.

	<u>West Virginia counties</u>			<u>Williamson wells</u>		<u>Kentucky counties</u>		
	<u>Wyoming</u>	<u>McDowell</u>	<u>Mingo</u>	<u>low flow</u>	<u>high flow</u>	<u>Pike</u>	<u>Martin</u>	<u>Floyd</u>
<b><u>Arsenic</u></b>								
<b><u>samples</u></b>	7	3	2	12	8	23	45	11
<b><u>%detect</u></b>	0	0	0	8	75	13	22	0
<b><u>%exceed</u></b>	0	0	0	0	25	0	9	0
<b><u>Lead</u></b>								
<b><u>samples</u></b>	7	3	2	12	8	25	45	11
<b><u>%detect</u></b>	0	0	0	50	88	28	18	45
<b><u>%exceed</u></b>	0	0	0	42	38	4	4	9
<b><u>Iron</u></b>								
<b><u>samples</u></b>	7	3	2	12	8	25	45	8
<b><u>%detect</u></b>	10	10	50	10	10	10	10	10
<b><u>%exceed</u></b>	86	10	0	75	10	80	80	50
<b><u>Manganese</u></b>								
<b><u>samples</u></b>	7	3	2	12	8	25	45	11
<b><u>%detect</u></b>	10	10	50	92	10	96	10	82
<b><u>%exceed</u></b>	10	10	50	75	10	76	67	36
<b><u>Sodium</u></b>								
<b><u>samples</u></b>	7	3	2	12	8	23	45	15
<b><u>%detect</u></b>	10	10	10	10	10	10	10	10
<b><u>%exceed</u></b>	10	10	10	83	75	91	82	10



Figures 1 & 2. Arsenic and lead concentrations in Williamson area well water in relation to other regional well water samples. Concentrations below detection limits are shown as zero. Bars indicate average concentration in each group. Dashed line indicates drinking water standards. Samples sizes shown in Table 4.



Figures 3 & 4. Iron and manganese concentrations in Williamson area well water in relation to other regional well water samples. Concentrations below detection limits are shown as zero. Bars indicate average concentration in each group. Dashed line indicates drinking water standards. Samples sizes shown in Table 4.

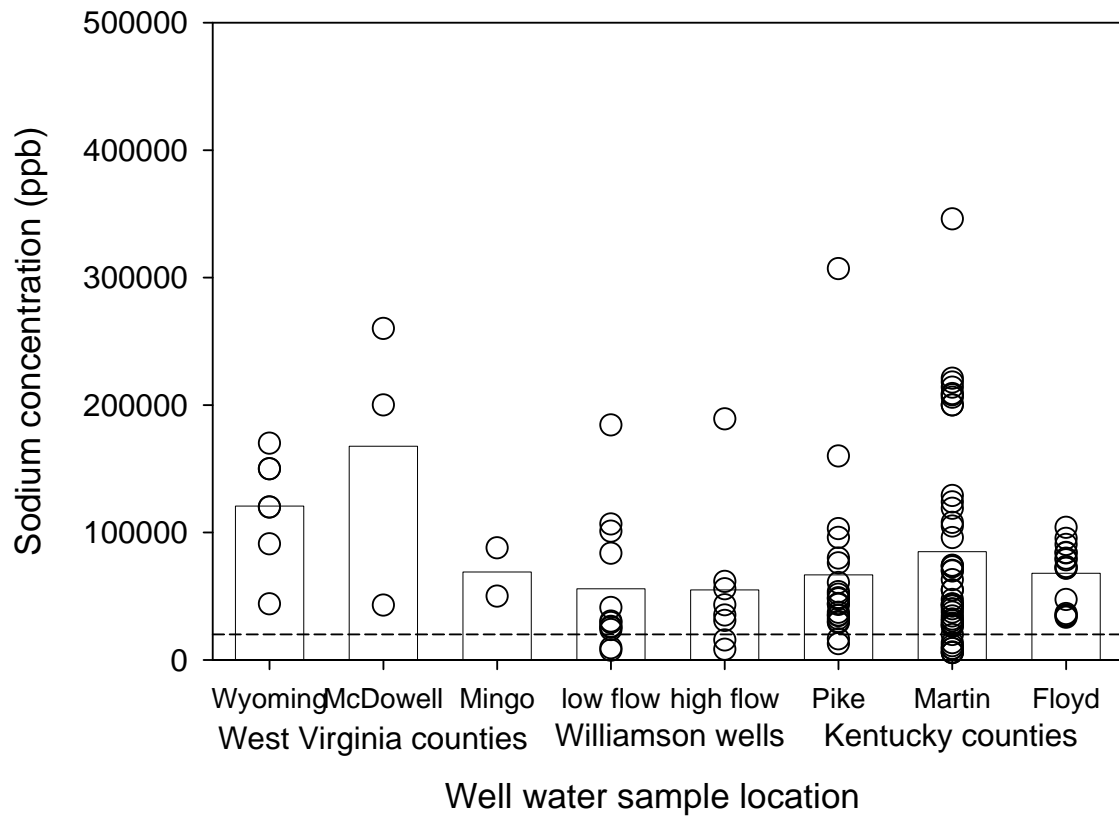


Figure 5. Sodium concentrations in Williamson area well water in relation to other regional well water samples. Concentrations below detection limits are shown as zero. Bars indicate average concentration in each group. Dashed line indicates drinking water standards. Samples sizes shown in Table 4.

## Discussion

### Water supply concerns

The results of this study indicate that well water quality in the area of Sprigg, Merrimac, Rawl, and Lick Creek near Williamson, West Virginia is unquestionably poor. Excessive levels of heavy metals, particularly lead and arsenic, may present a chronic health hazard to those families exposed to wells. Exposure may occur from inhalation and ingestion during bathing, using tap water in icemakers, and from contact with well water during washing in sinks, dishwashers and washing machines; particularly when hot water is used. Hot water heaters act to concentrate metals prior to delivery to the household system.

The metals found in Williamson area wells are commonly associated with coal mining activities, and these levels may be confounded by historic mining practices or exacerbated by recent drilling activities. However, iron at levels up to 57,588 ppb and manganese at levels up to 4,063 ppb indicates that Williamson area wells may be subjected to coal slurry contamination. Samples of coal slurry liquids collected in 1985 from the Pond Fork coal slurry impoundment yielded 3,833,000 ppb of iron and 20,000 ppb of manganese (US EPA, 1985). Likewise, slurry samples from the Big Branch Impoundment in Martin County, KY, had 10,700,000 ppb iron and 53,500 ppb manganese (US EPA, 2001).

Arsenic is common in coal and associated shale, and is adsorbed onto iron oxides and oxyhydroxides (Fisher, 2002). Iron hydroxide ( $\text{Fe}(\text{OH})_3$ ), commonly referred to as “yellow boy,” is the most common form of iron in oxygenated water (Wetzel, 1975) and appears to be the primary cause of red staining on clothes and porcelain in the households visited during this study. The reddish sludge collected from the bottom of the hot water heater had 557,700 ppb iron and 150 ppb arsenic. The non-detects of arsenic under low flow conditions followed by detects in 3 of 5 wells during high flow may be related to the arsenic-iron flocculent complex in the study wells.

The levels of metals found in Williamson area wells are greater than metals found in water supply wells in neighboring counties in southern West Virginia and eastern Kentucky. Although there is very little domestic well data available in this region, several of the few wells that have been tested in Pike and Martin Counties, Kentucky are also of serious concern. Nonetheless, metals were detected and standards exceeded in a greater percentage of Williamson area wells than in other coalfield region wells. Arsenic concentrations greater than 10 ppb are rare in Kentucky groundwater (Fisher & Goodmann, 2002). The Williamson area wells studied rank among the poorest in the nation in terms of arsenic (Welch, *et al*, 2000).

Metal concentrations in Williamson area well water repeatedly violated US EPA standards developed for public water supply sources. While most of our samples were from private wells, only the spring, a dug well, and 5 of the 14 drilled wells tested appear to be reasonable sources of drinking water. Seven of 14 drilled wells exceeded primary drinking water standards. Thirteen of the 14 drilled wells exceeded secondary drinking water standards. Although secondary standards are considered to impart taste and odor

concerns more so than health concerns, the concentrations witnessed in these wells was extraordinary. For instance, in one well iron was 192 times greater than the secondary standard. Another well had manganese at 81 times greater than the secondary standard.

### Sources of contamination

A considerable amount of effort has been directed at assessing source water quality in the area. Well water quality analyses done by the E.L. Robinson Engineering Company for the West Virginia Department of Environmental Protection (WVDEP, 2001) concluded that “the only feasible and permanent solution to the water quality problem of the study area is an extension of the Mingo County PSD’s water system.” The study also concluded that “the interview and water analysis phases of this study indicated severe problems with ground water sources within the study area.”

Nonetheless, the Agency for Toxic Substances and Disease Registry (ATSDR) in conducting a Public Health Consultation in the Lick Creek area concluded that sites studied, including the Rawl Sales and Processing mine site, are not a public health hazard (ATSDR, 2004). Concurrently, ATSDR recommended that a) persons drinking groundwater from this area should consult with a doctor to see if they should restrict manganese in their diets or from other sources, such as multivitamins or mineral supplements b) persons with liver or gastrointestinal disease should consult a doctor to see if they should avoid ingestion of water in this area, water that is high in manganese, and c) infants should not be fed dry formula mixed with groundwater that is high in manganese and/or sulfates. Interestingly, within that same report it is stated that “coal mining activities can add many minerals to the groundwater such as iron, manganese, and sulfur.” High iron, manganese and sulfate levels have long been considered indicators of water pollution from mining; however, other metals regulated by primary drinking water standards are also associated with mining and drilling. No such heavy metal data was available for ATSDR review.

Coal slurry has been injected into deep mines in this area since the 1980s (ATSDR, 2004). A study conducted by the West Virginia Department of Environmental Protection indicated that some of the wells along lower Lick Creek may have residue from slurry injection (WV DEP, 1995). The ATSDR (2004) study stated that chemicals in the mine would be “diluted with mine water, and the longer the sludge is in the mine, the greater the potential for dilution.” This may be so, but the “dilution effect”, as evidenced by the new data presented herein, is still not enough to achieve water quality standards.

In their report ATSDR (2004) stated that “the nature of chemicals, if any, in the sludge that spilled into Lick Creek is unknown.” While the chemical constituents of coal slurry certainly require further study (National Academy of Sciences, 2002), some data were available to ATSDR regarding the chemical composition of slurry. For instance, ATSDR was involved in a study regarding a 309 million gallon coal slurry spill at Martin County Coal Corporations Big Branch Impoundment near Inez, Kentucky in October, 2000. The ATSDR’s final report, dated April 22, 2003, included data indicating that coal slurry solids contained arsenic at up to 8,000 ppb and lead at up to 21,000 ppb (ATSDR, 2003a). Moreover, a stream water sample collected in Coldwater Creek a week after the spill had 86 ppb arsenic and 430 ppb lead (US EPA, 2000). The administrative record

(US EPA, 2001) also contained slurry chemistry data that was collected by Eastern Coal Corporation as part of a consent order on a Superfund site near McAndrews, Kentucky, approximately 4 air miles south of Williamson (US EPA, 1985). Eastern Coal Corporation began underground injection of coal slurry into an abandoned mine in January, 1984. In November, 1984 citizens in the surrounding area complained of possible contamination of their water supply. In February, 1985 EPA ordered Eastern Coal Corporation to cease injecting slurry until it received an Underground Injection Control permit because “the slurry being injected by Eastern contained contaminants which were likely to enter a public water supply and may present an imminent and substantial endangerment to human health.” The water from the coal slurry sample collected by Eastern contained, among other contaminants, 1,820 ppb arsenic and 3,890 ppb lead. In March, 1985 Eastern provided citizens with a connection to the water system to the Williamson, West Virginia water supply and Eastern was allowed to resume slurry injection (EPA, 1985).

Prior to the current study no arsenic testing had been done in the communities of Sprigg, Merrimac, Rawl, and Lick Creek. Although arsenic was mentioned in the ATSDR report in response to a claim of a poisoned child, the agency stated that no data could be obtained to assess this claim and that the child had moved away from the area. The ATSDR maintained that the exposure pathway no longer exists because 2 households that had used spring water are now supplied with well water. The conclusions of the report state that there is no apparent public health hazard with regard to possible contamination from 3 sites including the Rawl Sales and Processing strip mine (ATSDR, 2004). The results of the current study conflict with those findings. The ATSDR ranks arsenic and lead as the top 2 substances on their 2003 priority list (ATSDR, 2003). The priority list is a list of 275 substances commonly found at Superfund sites “which are determined to pose the most significant potential threat to human health due to their known or suspected toxicity and potential for human exposure” at Superfund sites on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) national priority list.

We recommend that ATSDR revisit the concerns of citizens regarding well water and health in the Williamson area. Additional well water testing should be conducted either by WV DEP or US EPA in support of a ATSDR health effects study. In addition to metals, a through analysis of volatile organic compounds, such as acrylamides and other additives used in the coal preparation process should be tested in order to identify source(s) of contamination. Should evidence of coal preparation residues mount, tracer dye, stable isotopes, or volatile organic chemicals unique to coal preparation plants could be measured to help identify the source(s) of contamination.

## **Conclusion**

This study supports the claims of citizens that their well water is contaminated and subject to “blackwater” events. Well water often contained black particles and yielded metal concentrations in excess of drinking water standards. This confirms that the well water being utilized by citizens in the area is polluted. Additional studies are required to determine the exact source of contamination; however, our data suggest that

coal-related activities may contribute to the pollution. Most of the households visited during the study reported health concerns related to water quality including kidney stones, cancers, and developmental issues regarding the young. Given the two-decade history of contaminated well water and associated health problems in the communities of Sprigg, Merrimac, Rawl, and Lick Creek, it is the opinion of the authors that a detailed, professionally administered study of the relationship between illness and well water quality should be conducted.

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# Lung cancer mortality is elevated in coal-mining areas of Appalachia

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Health disparities;  
Environmental health

**Summary** Previous research has documented increased lung cancer incidence and mortality in Appalachia. The current study tests whether residence in coal-mining areas of Appalachia is a contributing factor. We conducted a national county-level analysis to identify contributions of smoking rates, socioeconomic variables, coal-mining intensity and other variables to age-adjusted lung cancer mortality. Results demonstrate that lung cancer mortality for the years 2000–2004 is higher in areas of heavy Appalachian coal mining after adjustments for smoking, poverty, education, age, sex, race and other covariates. Higher mortality may be the result of exposure to environmental contaminants associated with the coal-mining industry, although smoking and poverty are also contributing factors. The knowledge of the geographic areas within Appalachia where lung cancer mortality is higher can be used to target programmatic and policy interventions. The set of socioeconomic and health inequalities characteristic of coal-mining areas of Appalachia highlights the need to develop more diverse, alternative local economies. © 2008 Elsevier Ireland Ltd. All rights reserved.

## 1. Introduction

Smoking is the primary cause of lung cancer, but about 10% of lung cancer cases occur in persons who are lifetime never smokers [1], and other cases may result from the interactive effects of smoking and exposure to environmental risks. Environmental causes of lung cancer include exposure to second-hand smoke [2], airborne particulates from

urban traffic or fossil fuel combustion [1,3–5], and exposure to ambient metals including zinc, chromium, copper, cadmium and nickel [6–8]. Arsenic exposure is a clear risk factor [9], including exposure through contaminated water supplies [10–12]. Other environmental risks include exposure to asbestos, polycyclic aromatic hydrocarbons [1] and radon [13–15].

Previous research identified higher lung cancer incidence and mortality in Appalachia compared to the rest of the country [16–18]. Furthermore, lung cancer incidence in rural portions of Appalachia is higher than in other rural areas of the United States [16]. Since Appalachia is primarily rural, higher lung cancer incidence and mortality is not attributable to factors unique to urban areas such as automobile exhaust or urban industry. Higher lung cancer

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incidence and mortality in Appalachia is thought to result from higher smoking rates and correlates of poor socioeconomic conditions characteristic of the region such as limited access to health care.

However, another factor to consider is the impact of Appalachian coal mining on the health of the resident population. Coal provides 40% of the world's electricity [19] and its mining constitutes a major industrial activity for eight Appalachian states (Alabama, Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia), where 389.9 million tons were mined in 2004 [20]. Residents of Appalachian coal-mining communities report exposure to contaminated air and water from coal-mining activities and express concerns for resulting illnesses [21], but empirical evidence on community health risks from coal-mining activities is limited [22–24]. Coal contains carcinogenic impurities including zinc, cadmium, nickel, arsenic and many others [25], and the mining and cleaning of coal at local processing sites creates large quantities of ambient particulate matter and contaminated water [26–28]. Shiber [29] reports elevated arsenic levels in drinking water sources in coal-mining areas of central Appalachia. Elevated lung cancer mortality rates previously identified within Appalachia may result from behaviors such as smoking and other correlates of the poor socioeconomic conditions prevalent in the area, but may also result from exposure to environmental contaminants. The objective of the current study was to determine whether elevated lung cancer mortality in Appalachia is attributable to smoking, poverty, education, and other demographics, or whether there is an additional effect linked to residence in intense coal-mining areas.

## 2. Methods

This study investigated lung cancer mortality rates for Appalachia and the nation for the years 2000–2004. Data were obtained from the Centers for Disease Control and Prevention (CDC) on lung cancer mortality rates. Mortality rates are measured at the county level per 100,000 population, age-adjusted using the 2000 U.S. standard population for mortality from cancer of the trachea, bronchus and lung (ICD-10 group code GR113-027) [30]. Coal production data were obtained from the Energy Information Administration [31–35], measured as tons of coal mined in the county from surface and underground mining combined. The primary analyses compared Appalachian coal-mining areas to other areas of Appalachia and to non-coal-mining counties outside Appalachia; 97 non-Appalachian coal-mining counties were excluded from analysis unless otherwise specified.

Levels of coal mining were not normally distributed across counties. Two primary analyses examined mortality effects based on alternative methods of measuring coal-mining exposure. The first grouped counties into three dummy variables: Appalachian coal mining up to 3 million tons combined over the 5 years 2000–2004, Appalachian coal mining greater than 3 million tons, and other counties (the latter used as the referent in regression models). The choice of 3 million tons divides Appalachian coal-mining counties approximately in half. The second estimated per capita exposure in Appalachia by dividing county tons mined by the county population from the 2000 Census;

counties were grouped into three levels: per capita exposure up to 100 tons per person, per capita exposure greater than 100 tons, and other counties (used as the referent).

A series of supplementary analyses were conducted to test for the robustness of findings across conditions. One set of analyses examined coal-mining effects based on alternative dummy variables at integer levels from 1 to 6 million tons. A second set correspondingly examined per capita exposure effects at increasing levels. A third examined whether differences in mortality rates were related to surface mining versus underground mining. A fourth examined whether mortality rates were elevated only in Appalachian coal-mining areas or in coal-mining areas outside of Appalachia, and whether differences in population density may be related to national variation.

Covariates were taken from the 2005 Area Resource File [36], CDC BRFSS smoking rate data [37] and the Appalachian Regional Commission (ARC) [38]. Covariates included percent male population, college and high school education rates, poverty rates, race/ethnicity rates, health uninsurance rates, physician supply, rural–urban continuum code, smoking rates, Southern state (yes or no) and Appalachian county. Selection of covariates was based on previously identified risk factors or correlates of lung cancer incidence or mortality [39–44]. Specific race/ethnicity groups included percent of the population who were African-American, Native American, Non-white Hispanic, and Asian American (using White as the referent category in regression models). Rural–urban continuum is scored on a nine-point scale from least to most rural; because the effects of this measure may be non-linear [45] this measure was recoded into three dummy variables representing metropolitan, micropolitan and rural or non-core areas (the latter used as the referent). Physician supply is the number of active MDs and DOs per 1000 population. Because residence in the South is associated with poorer health status and higher mortality risk [46,47] a dichotomous Southern variable was created to capture regional effects that partially overlap with Appalachia; Southern states included Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia. CDC BRFSS smoking rates were available for states and some county-based metropolitan areas, supplemented with county rates available from some state public health websites; the state average was used when the county rate was not available. Appalachian counties included the 417 counties and independent cities in 13 states as defined by the ARC [38].

Analyses were conducted using bivariate correlations, general linear models and ordinary least squares regression models to test for the association between residence in coal-mining areas and lung cancer mortality, without and with control for covariates. Post hoc tests employed the Ryan–Einot–Gabriel–Welsch test to adjust for Type I error. The study is an analysis of anonymous, secondary data sources and met university Internal Review Board standards for an exemption from human subjects review.

## 3. Results

First, we confirmed that age-adjusted lung cancer mortality was in fact significantly higher in Appalachia compared

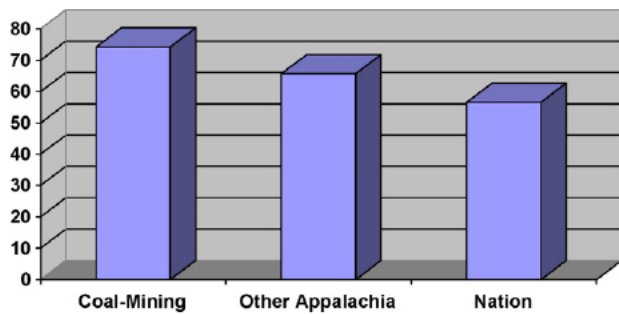


Fig. 1 Age-adjusted lung cancer mortality per 100,000, years 2000–2004.

to the nation: 67.06 versus 56.55 per 100,000 (two-tailed  $t=12.67$ , d.f.=3026,  $p<.0001$ ). There was also a significant gradient effect comparing three groups: lung cancer mortality was highest in heavy coal-mining areas (74.21), followed by all other areas of Appalachia (65.70) and the nation (56.55);  $F=88.91$ , d.f.=2 and 3025,  $p<.0001$ ; post hoc tests correcting for Type I error found all means significantly different at  $p<.05$  (see Fig. 1).

Table 1 summarizes study variables for heavy coal areas, other Appalachian areas, and the rest of the nation, based on the definition of coal mining as Appalachian counties with greater than 3 million tons mined from 2000 to 2004, and deleting coal-mining areas outside Appalachia. Poverty, college education, and smoking rates show the same relationship: these measures are least favorable in heavy coal-mining areas, and intermediate in the rest of Appalachia, compared to the rest of the country. Coal-mining areas are characterized by proportionately small race/ethnicity minority populations. Rates of health insurance were different in the omnibus  $F$ -test but post hoc tests showed that means were not significantly different.

Rural–urban status and per capita supply of doctors did not differ across these groups of counties.

Bivariate correlations were examined to test for multicollinearity among independent variables. The county poverty rate was highly correlated to percent of the population without health insurance ( $r=.82$ ); because preliminary regression models revealed that poverty was related to lung cancer mortality but insurance was not, the insurance variable was dropped from further analysis. Heavy coal-mining areas correlated significantly with other risk factors but not at levels indicating multicollinearity, including smoking ( $r=.23$ ), high school education ( $r=-0.12$ ), college education ( $r=-0.10$ ) and poverty ( $r=.12$ ).

The results of the two primary regression models are shown in Table 2. The table includes both unstandardized coefficients and standardized Betas ( $B$ ). The results of the two coal exposure specifications were very similar. Living in Appalachian areas where lower levels of coal mining took place did not increase lung cancer mortality risk, but areas of heavy mining were associated with significantly higher adjusted lung cancer mortality. Higher age-adjusted lung cancer mortality was associated with smoking rates, urban residence, poverty, living in the South, percent male population and lower education. Residence in Appalachia was related to lower lung cancer mortality after adjusting for poverty, coal mining and other variables. A greater supply of physicians was related to higher mortality rates. The African-American and Hispanic variables were related to lower adjusted mortality. Examination of standardized Betas indicates that the strongest effects were for smoking, poverty, lack of high school education, residence in metropolitan counties and the Hispanic population variable.

The race effect was examined further. In a forward inclusion regression model of national data beginning with the four race/ethnicity variables, the variable measuring percent Native Americans was not related to lung cancer mortality, a higher percent of African-Americans was

Table 1 Summary of study independent variables by geographic location

	Heavy Appalachian coal mining (N = 66)	Other Appalachian (N = 347)	Rest of Nation (N = 2615)	F or $\chi^2$ , p
Smoking rate <sup>a</sup>	27.7	25.2	21.7	<.0001
Percent male <sup>b</sup>	49.1	49.5	49.9	<.0001
Percent African-American <sup>c</sup>	3.1	7.3	9.5	<.0002
Percent Native American <sup>d</sup>	0.2	0.4	2.1	<.0001
Percent Hispanic <sup>b</sup>	0.7	1.8	7.3	<.0001
Percent Asian American <sup>b</sup>	0.4	0.5	1.0	<.0001
High school education <sup>b</sup>	70.0	71.4	78.3	<.0001
College education <sup>a</sup>	11.4	13.5	17.1	<.0001
Poverty rate <sup>a</sup>	18.2	14.9	13.3	<.0001
Percent metropolitan counties	27.3	34.0	35.4	<.36
Percent micropolitan counties	21.2	24.2	21.8	<.58
Percent counties in the South <sup>a</sup>	33.3	68.6	20.0	<.0001
Percent without health insurance <sup>d</sup>	14.3	13.7	14.8	<.0005
Mean physicians per 1000	1.49	1.31	1.32	<.62

<sup>a</sup> Post hoc tests significantly different between all three means.

<sup>b</sup> Coal mining and Appalachian areas significantly different from the nation.

<sup>c</sup> Coal-mining areas significantly different from Appalachia and the nation.

<sup>d</sup> Post hoc differences between means not significant.

**Table 2** Ordinary least squares regression model, age-adjusted lung cancer mortality rate

	Coal exposure measured in tons <sup>a</sup>				Coal exposure measured per capita <sup>b</sup>			
	Coefficient	S.E.	p	B	Coefficient	S.E.	p	B
Intercept	58.60	8.45	<.0001		58.66	8.44	<.0001	
Coal mining up to 3 million tons	−0.15	1.77	<.93	−0.001	—	—	—	—
Coal mining ≥3 million tons	3.72	1.77	<.036	.034	—	—	—	—
Coal mining up to 100 tons per person	—	—	—	—	−0.46	1.71	<.79	−0.004
Coal mining ≥100 tons per person	—	—	—	—	4.49	1.84	<.015	.039
Appalachia	−2.96	0.90	<.002	−0.63	−2.93	0.90	<.0002	−0.063
Smoking rate	0.94	0.08	<.0001	.210	0.94	0.08	<.0001	.209
Percent male	0.25	0.13	<.06	.028	0.25	0.13	<.06	.028
Percent African-American	−0.07	0.02	<.002	−0.067	−0.07	0.02	<.003	−0.066
Percent Native American	−0.04	0.04	<.21	.020	−0.04	0.03	<.22	−0.020
Percent Hispanic	−0.45	0.03	<.0001	−0.344	−0.45	0.03	<.0001	−0.343
Percent Asian American	0.15	0.11	<.20	.021	0.14	0.11	<.21	.021
High school education	−0.49	0.06	<.0001	−0.269	−0.50	0.06	<.0001	−0.268
College education	−0.30	0.05	<.0001	−0.146	−0.30	0.05	<.0001	−0.146
Poverty rate	0.52	0.08	<.0001	.195	0.52	0.08	<.0001	.184
Metropolitan	9.11	0.63	<.0001	.271	9.13	0.63	<.0001	.271
Micropolitan	4.03	0.62	<.0001	.104	4.07	0.62	<.0001	.105
South	2.16	0.76	<.004	.059	2.15	0.76	<.005	.059
Primary care physicians per 1000	0.85	0.22	<.0001	.074	0.86	0.21	<.0001	.075

<sup>a</sup>  $F = 122.6$  (16, 3010),  $p < .0001$ ; adjusted  $R^2 = .39$ .

<sup>b</sup>  $F = 122.8$  (16, 3010),  $p < .0001$ , adjusted  $R^2 = .39$ .

related to higher rates, and Asian American and Hispanic variables were related to lower rates of lung cancer mortality. The effect for the African-American variable became significant and negative after adding high school education, poverty rate, smoking rate and metropolitan county status. That is, the apparent lower lung cancer mortality rate among African-American minorities is due to the confound of socioeconomic variables with race variables.

The sensitivity of Table 2 results was examined by running regression models based on different levels of coal mining and per capita exposure. A summary of these models is provided in Table 3. The table shows the unstandardized coal-mining beta coefficient and  $p$  level based on alternative specifications of high levels of coal-mining exposure. (The full regression model results for these various specifications are not shown, but they are almost identical to Table 2 results.) The effect of the coal-mining exposure variable was significant for all levels and both specifications, except for the lowest level of exposure measured in tons. Furthermore, the size of the beta coefficient increases with greater exposure, indicating an increasing number of adjusted deaths per 100,000.

To estimate number of deaths, the population of Appalachian coal-mining areas was found from the 2000 Census ( $N = 3,875,656$  based on counties with more than 3 million tons of coal mined). Translating the age-adjusted

death rate from Table 1 into population figures, the difference between Appalachian coal-mining areas and the national rate equates to 684 excess lung cancer deaths in coal-mining areas. Most of the Appalachian coal-mining disparity is the result of factors such as poverty and smoking, but after adjusting for all covariates, translating the Table 2 beta coefficient (3.72) into number of deaths per 100,000 indicates that Appalachian coal-mining counties are still associated with an excess of 144 deaths from lung cancer over the years 2000–2004.

Exposure to Appalachian coal-mining activity was also significantly related to lung cancer mortality when coal mining was measured separately for surface and underground mines. Elevated mortality was found to be specific to Appalachia; mortality was not significantly higher in non-Appalachian areas where heavy coal mining took place. Table 4 shows the coal-mining beta coefficients and  $p$  levels for these tests, controlling for other covariates, and based on the definition of more than 3 million tons of coal. The largest coefficient was found for Appalachian surface mining. We examined whether the distinction between Appalachian and non-Appalachian mining might be related to population density. We found that population density was significantly higher in Appalachian coal-mining areas (95.5 people per square mile) than in other coal-mining areas (43.0 people per square mile; Satterthwaite

**Table 3** Effect of high level of Appalachian coal-mining exposure on adjusted lung cancer mortality, based on alternate specifications of exposure

Tons of coal in millions	Coefficient	<i>p</i>	Per capita exposure (tons)	Coefficient	<i>p</i>
1	2.41	<.13	50	4.12	<.014
2	3.42	<.041	100	4.49	<.015
3	3.72	<.036	150	3.90	<.044
4	3.63	<.044	200	5.34	<.010
5	4.05	<.036	250	5.54	<.009
6	4.71	<.017	300	5.59	<.009

correction for unequal variances  $t = 4.44$ , d.f. = 117 and  $p < .0001$ ).

Some research suggests that coal miners may be at elevated risk for lung cancer, although the evidence is equivocal [48]. To address the possibility that our results are due to current or former miners who live in coal-mining areas, we conducted an additional regression model limited to the heavy Appalachian coal-mining counties ( $N = 66$ ). This model is based on the fact that almost all coal miners are men. Within these counties, percent male population was not related to lung cancer mortality ( $t = -0.71$ ,  $p < .48$ ). The fact that populations with higher percentages of males are not at higher risk suggests that the effect in coal-mining locations is likely not the result of current or former miners who live in the area and who were directly exposed through occupational hazards. In addition, based on employment figures provided by the Energy Information Administration [49], coal miners constitute only about 1% of the Appalachian population in heavy coal-mining areas.

#### 4. Discussion

Lung cancer mortality is higher in Appalachia because of smoking and the correlates of poverty and low education, but an additional risk factor is living in heavy coal-mining areas. Living in these areas may expose residents to pollution from the coal-mining industry, or may be associated with additional behavioral or demographic characteristics not captured through other covariates. Access to health care as measured by insurance rates and doctor supply is not an explanation for higher lung cancer mortality, consistent with other research showing that coal-mining areas with an adequate supply of primary care providers still experience increased health problems [50]. To eliminate lung cancer mortality disparity in Appalachia, it is necessary to continue efforts to reduce smoking and improve socioeconomic conditions; however, because coal-mining location is an independent risk factor, and because coal mining overlaps

with other known risks including smoking, education, and poverty, targeting anti-smoking and socioeconomic improvement interventions to these areas may be a cost-effective strategy. Policies that would improve environmental quality in coal-mining areas are also suggested by these results.

The possibility that environmental contamination from the coal-mining industry causes lung cancer is consistent with known risks linked to coal. Toxins found in coal are well-established carcinogens [51]. The release of particulate matter and toxins from burning coal is a lung cancer risk factor [1,52–55]. There is also an abundance of information on the deleterious health consequences of working as a coal miner, including increased risk for pneumoconiosis, heart disease, chronic obstructive pulmonary disease and perhaps lung cancer [49,56,57]. Exposure to particulate matter or toxic impurities from the coal-mining industry may extend to the general population. The coal-mining industry includes not only the mining of coal, but also its processing, storage and transport, and the resulting local water and air pollution can be severe [26–29,58] and may result in increased lung cancer among community residents. The suggestion that the results may be stronger for exposure to surface mining operations relative to underground mining suggests the likelihood of greater exposure to airborne particulates from surface mining operations.

Limitations of the study include the reliance on secondary county-level data and the limited measures of coal-mining exposure. Causes of individual lung cancer cases cannot be identified, and the precise pathway between residence in coal-mining areas and lung cancer is unknown. Smoking rates were imprecisely measured and smoking effects, including exposure to second-hand smoke linked to poorer socioeconomic conditions, may be underestimated. Demographic or cultural variables not captured through available covariates may be contributing factors; these variables might include Appalachian cultural beliefs such as fatalism [59] that increase risk for poor health behaviors or lack of

**Table 4** Adjusted regression coefficients and *p*-values based on type of mining, and Appalachian or non-Appalachian coal-mining areas

	Surface mining	Underground mining	Combined
Appalachia coal mining	5.60 ( $p < .008$ )	4.55 ( $p < .024$ )	3.72 ( $p < .036$ )
Non-Appalachian coal mining	1.11 ( $p < .57$ )	1.79 ( $p < .47$ )	2.04 ( $p < .21$ )

early health care intervention, or weak tobacco control policies that increase second-hand smoke exposure. Future research should improve measures of coal-mining exposure by distinguishing aspects of the mining industry, including post-mining processing facilities, and mountaintop removal mining from other forms of surface mining, and relating these aspects to health indicators. Additional research is also needed to identify exposure routes (i.e., air, water and soil), exposure levels and biological mechanisms of action that can account for higher lung cancer mortality in Appalachian coal-mining areas.

The results of this study may be linked to a growing body of evidence demonstrating increased health risks across a spectrum of indicators associated with residence in Appalachian coal-mining areas. This evidence includes higher mortality rates for all causes and for cardiopulmonary conditions [60], increased hospitalization risk for hypertension and chronic obstructive pulmonary disease [23], and increased rates of self-reported chronic illness and lower health status [22]. These findings are not simply the result of poverty or other demographic variables, although poverty is a contributing factor.

Regardless of whether causes are environmental, behavioral or economic, it is clear that populations in coal-mining areas are at risk for a host of health problems. Those areas of Appalachia where poverty has been most persistent over time are characterized by single source economies including tobacco and coal [38]. Based on social inequalities models [61], addressing the health disparities of coal-mining communities requires developing economies that offer more diverse job opportunities at lower environmental cost, enacting and enforcing environmental protection policies, improving support for educational development, and creating built environments that are conducive to health and wellness.

## Conflict of interest

None.

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# Hospitalization Patterns Associated with Appalachian Coal Mining

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The goal of this study was to test whether the volume of coal mining was related to population hospitalization risk for diseases postulated to be sensitive or insensitive to coal mining by-products. The study was a retrospective analysis of 2001 adult hospitalization data ( $n = 93,952$ ) for West Virginia, Kentucky, and Pennsylvania, merged with county-level coal production figures. Hospitalization data were obtained from the Health Care Utilization Project National Inpatient Sample. Diagnoses postulated to be sensitive to coal mining by-product exposure were contrasted with diagnoses postulated to be insensitive to exposure. Data were analyzed using hierarchical nonlinear models, controlling for patient age, gender, insurance, comorbidities, hospital teaching status, county poverty, and county social capital. Controlling for covariates, the volume of coal mining was significantly related to hospitalization risk for two conditions postulated to be sensitive to exposure: hypertension and chronic obstructive pulmonary disease (COPD). The odds for a COPD hospitalization increased 1% for each 1462 tons of coal, and the odds for a hypertension hospitalization increased 1% for each 1873 tons of coal. Other conditions were not related to mining volume. Exposure to particulates or other pollutants generated by coal mining activities may be linked to increased risk of COPD and hypertension hospitalizations. Limitations in the data likely result in an underestimate of associations.

Over the past several years, coal has become more competitive as a source of power and fuel because of (1) energy security concerns, (2) an increase in the cost of oil and gas, (3)

evidence for the near-term occurrence of peak global oil production, and (4) concerns about nuclear power. The United States has 27% of all known coal reserves (Folger, 2006). The U.S. Department of Energy estimates that 153 new coal-fired power plants will come on line by 2030 (Klara & Shuster, 2007). Increases in coal mining in response to these pressures pose potential adverse health risks for persons who live in the vicinity of the mining activities.

Anecdotal evidence on the negative health effects of living near coal mining sites in Appalachia is widespread. Residents reported serious health consequences they experience from living in the coalfields (Goodell, 2006). Water quality studies documented contaminated well water in West Virginia and Kentucky communities consistent with coal slurry toxins (McSpirit & Dieckmann, 2003; Stout & Papillo, 2004). However, quantitative research on the relationship between residential proximity to coal mining sites and health consequences is rare; research conducted has been limited to studies in Great Britain and to a narrow range of respiratory illnesses. These studies found elevated levels of particulate matter (PM) (Pless-Mulloli et al., 2000a) and increased symptoms of respiratory morbidity (Pless-Mulloli et al., 2000b; Brabin et al., 1994; Temple & Sykes, 1992) associated with residential proximity to coal mining sites. Contaminated dust from coal washing activities is a significant local phenomenon (Ghose & Banerjee, 1995). The harmful exposures faced by coal miners—diesel particulates, dust, chemicals, fuels, and elemental toxins (Scott et al., 2004)—may be found in less concentrated form but for larger populations of individuals living near the mining sites.

Previous research has established an association between hospitalization patterns and daily measures of air pollution in metropolitan areas (Simpson et al., 2005; Wellenius et al.,

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2006; Barnett et al., 2006; Yang et al., 2004; 2007). These hospitalizations, for cardiovascular disease, asthma, and other respiratory diseases, are thought to result from exacerbations of existing illnesses from PM. A similar phenomenon may exist for residents exposed to pollution from coal mining activities. However, previous research on residential proximity to coal mining (Pless-Mullooli et al., 2000b; Brabin et al., 1994; Temple & Sykes, 1992) has not examined hospitalization patterns. Therefore, the current study examines the relationship between hospitalization patterns and coal mining production among residents of three Appalachian states in the United States: Kentucky, Pennsylvania, and West Virginia.

## METHODS

### Design

The study is a retrospective analysis of 2001 person-level hospitalization data from Kentucky, Pennsylvania, and West Virginia, merged with 2001 county-level data on tons of coal mined and other county-level data.

### Sample and Data Sources

Hospital data are taken from the Health Care Utilization Project (HCUP) National Inpatient Sample (NIS) of short-stay general hospitals for 2001. These data are coordinated through the Agency for Healthcare Research and Quality (AHRQ), and are available as de-identified discharge abstracts for research purposes. The NIS data represents approximately a 20% probability sample of all hospitals in participating states. For the current study, adults 19 yr and older with all diagnoses were included, except for maternal cases and transfers from other hospitals, resulting in a sample of 93,952 hospitalizations from 90 sampled hospitals. Maternal cases were excluded so as not to confound denominators in the hospitalization rates with normal labor and delivery, instead limiting the denominator to forms of illness or injury. Not every state participates in the NIS, and among those that do, only some provide the county identifier field. Among major coal-producing Appalachian states, counties were identified in the NIS data by Kentucky, Pennsylvania, and West Virginia, and thus are included in this study.

Coal production figures for 2001 were obtained from the Energy Information Administration (Annual Coal Report, 2002). The figures included the tons of coal mined in thousands from each county in both underground and surface mines. There were 73 counties represented in this database (including counties that mined no coal) with matching records in the NIS sample.

Other county indicators included percent of population in poverty from U.S. Census data, and a measure of county production of social capital, standardized to a mean of 0 across all counties in the nation (Rupasingha et al., 2006). Social capital has been shown in other research to be an important correlate of population health (Lochner et al., 2003).

### Variables

NIS variables used for analysis include patient age (in years, categorized as 19–44, 45–64, 65–74, 75+), gender, payer (insured or uninsured), diagnoses, and hospital teaching status (teaching hospitals are academic health centers that conduct patient care, research, and medical education, and that tend to serve most complex cases). The Federal Information Processing Standards (FIPS) code was used to identify the county location of the hospital. The dependent variable was found from the diagnosis given in the primary diagnostic field. Diagnoses were grouped into those postulated to be “coal exposure sensitive” and “coal exposure insensitive.” The list of candidates for sensitive conditions is preliminary and based on previous health risks reported in the literature for coal miners, findings established from exposure to air particulate pollution, or evidence for kidney or cardiovascular disease related to exposure to toxins found in association with coal mining (Wellenius et al., 2006; Barnett et al., 2006; Navas-Acien et al., 2004, 2005; Nishijo et al., 2006; Coggon & Taylor, 1998; Sarnat et al., 2006; Noonan et al., 2002). Where to place lung cancer is unclear; risk of lung cancer was linked to diesel particulate matter (Monforton, 2006), but other research found no elevated risk for lung cancer among miners after controlling for smoking behavior (Montes et al., 2004); for this study lung cancer was tentatively positioned in the “sensitive” column. A list of postulated coal exposure-sensitive and -insensitive conditions is provided in Table 1. The list of potential insensitive conditions is not intended to be final or exhaustive but to offer a sample of “control” conditions that are expected to be unrelated to coal mining exposure. Each diagnosis is thus a dichotomous variable, and the question becomes whether an exposure-sensitive diagnosis is significantly higher in coal mining areas as a proportion of total hospitalizations, whereas

**TABLE 1**

List of Potential Candidates for Coal-Sensitive and Coal-Insensitive Conditions, With Corresponding Diagnostic Codes

Coal-sensitive		Coal-insensitive	
Category	ICD-9 codes	Category	ICD-9 codes
Lung cancer	162	Diabetes	250
COPD	490–492, 494–496	Musculoskeletal and connective	710–739
Hypertension	401–405	Organic psychoses	290–294
Kidney disease	580–589		
Congestive heart failure	428		
Ischemic heart disease	410–413		
Asthma	493		

exposure-insensitive conditions should not differ as a function of coal mining intensity.

Other NIS variables are used as covariates. These include age, gender, uninsurance, hospital teaching status, and comorbidities. Comorbidities are measured in two ways: first, by the count of nonmissing secondary diagnosis fields ranging potentially from 0 to 14, and second, by a Charlson index (Charlson et al., 1987) calculated for each case based on diagnostic codes reported by Romano et al. (1993) and scored 0 to 3 to indicate increasing severity of comorbidities.

Coal production was not normally distributed across counties. Because more than half of the counties produced no coal, a square-root transformation was preferred over a log transformation. The coal production variable was transformed by taking the square root of tons of coal measured in thousands. The coal production variable was linked to the hospital records at the county level.

## Analysis

After descriptive analyses, inferential analyses determined whether hospitalizations for “exposure-sensitive” and “exposure-insensitive” conditions were significantly elevated as a function of coal production, accounting for other variables likely to correlate with health indicators. The analysis was done at the person level using HLM 6.03 multilevel Bernoulli modeling for the dichotomous presence of the dependent variable diagnosis. The square root of county-level coal production was included as a level 2 predictor. Level 1 (person-level) covariates included gender, age, uninsurance status, hospital teaching status, comorbidity count, and Charlson index. Level 2 (county-level) covariates included social capital and poverty rates. The intercept effect was treated as a random variable but other predictors were treated as fixed. Results are reported for final population estimates with robust standard errors. Significant coal effects are identified based on odds ratios greater than 1 at the 95% confidence interval.

Additional analyses examined gender differences to confirm that coal effects were not limited to men, who may be current or former miners, and to examine scatterplots between observed and expected level 2 residuals to confirm adequate model fit.

## RESULTS

Table 2 summarizes descriptive characteristics of study variables. The average age of the sample was about 67, and about 56% of patients were female. The most common diagnoses among those coded for analysis were congestive heart failure, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and diabetes.

Table 3 summarizes hierarchical model results. Greater coal mining was positively related to more hospitalizations for two postulated coal-sensitive conditions, hypertension and COPD.

**TABLE 2**  
Descriptive Summary of Study Variables

Variable	Mean or %	St. deviation	Minimum– maximum
Person-level ( <i>n</i> = 93,952)			
Mean age	66.9	14.3	19–105
Mean comorbidity count	4.12	2.10	0–9
Mean Charlson index	0.41	0.65	0–3
Percent female	55.7		
Percent uninsured	1.57		
Percent teaching hospital admissions	33.2		
Percent with primary diagnosis of:			
COPD	3.33		
Asthma	0.92		
Hypertension	1.39		
Kidney disease	1.09		
Congestive heart failure	9.61		
Ischemic heart disease	4.57		
Diabetes	7.62		
Lung cancer	0.40		
Organic psychoses	0.49		
Musculoskeletal and connective disorders	3.83		
County-level ( <i>n</i> = 73)			
Tons of coal×1000	1957.70	6643.16	0–44303
Square root (tons of coal×1000)	20.94	39.25	0–210.48
Percent population below poverty	15.22	6.69	4.8–37.7
Social capital index	-0.17	0.42	-1.14–0.50

It was not significant for other conditions, including the potential insensitive conditions. There was a significant *negative* relationship between coal production and hospitalization for lung cancer and kidney disease.

The odds ratios are expressed relative to the square root of coal in thousands of tons. Transforming the odds ratios back to the original metric results in the odds of a COPD hospitalization increasing 1% for each 1462 tons of coal, and the odds for a hypertension hospitalization increasing 1% for each 1873 tons of coal.

The possibility that the results may reflect current or former miners who live in the area, rather than a general population effect, may be dismissed through an examination of gender effects. Almost all coal miners are men. Results for the significant COPD model show no gender effect, and results for the significant hypertension model show a higher risk for women.

**TABLE 3**  
Hierarchical Model Results, Coal Production Effects Controlling for Person and County Covariates

Independent variables	COPD		LUNG CANCER	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Coal production	1.003	1.001–1.006	0.997	0.993–1.000
County poverty rate	1.017	0.987–1.048	1.010	0.966–1.056
Social capital	–0.467	0.416–0.945	1.205	0.641–2.266
Age	1.154	1.098–1.213	1.216	1.076–1.374
Female	0.979	0.870–1.102	0.681	0.545–0.851
Teaching status	0.789	0.584–1.065	1.775	0.931–03.382
Comorbidity count	0.918	0.901–0.935	0.878	0.823–0.936
Charlson Index	0.664	0.600–0.735	3.602	3.220–4.029
Uninsured	0.681	0.464–0.999	0.238	0.079–0.714
	Hypertension		Diabetes	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Coal production	1.003	1.001–1.005	0.998	0.994–1.001
County poverty rate	0.992	0.957–1.027	1.045	0.980–1.113
Social capital	0.701	0.413–1.190	1.504	0.614–3.685
Age	1.086	1.033–1.141	0.605	0.582–0.629
Female	1.218	1.061–1.399	0.899	0.849–0.951
Teaching status	1.236	0.707–2.158	0.978	0.833–1.147
Comorbidity count	0.977	0.944–1.012	0.906	0.885–0.928
Charlson Index	0.913	0.847–0.985	0.983	0.936–1.033
Uninsured	1.739	0.976–3.098	1.808	1.559–2.098
	Kidney disease		Organic psychoses	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Coal production	0.997	0.994–0.999	0.998	0.994–1.001
County poverty rate	1.000	0.972–1.030	1.003	0.965–1.043
Social capital	0.639	0.408–1.000	1.812	0.833–3.941
Age	1.077	1.010–1.149	1.251	0.986–1.589
Female	1.005	0.908–1.112	0.563	0.465–0.681
Teaching status	1.269	0.975–1.635	0.509	0.151–1.717
Comorbidity count	1.441	1.352–1.536	1.025	0.918–1.145
Charlson Index	0.909	0.807–1.024	0.702	0.590–0.835
Uninsured	0.465	0.192–1.130	1.039	0.452–2.392
	Ischemic heart disease		Musculoskeletal	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Coal production	0.998	0.995–1.002	1.002	1.000–1.004
County poverty rate	1.002	0.973–1.032	0.985	0.957–1.014
Social capital	0.957	0.643–1.428	2.629	1.653–4.181
Age	1.108	1.066–1.151	0.987	0.938–1.039
Female	0.733	0.697–0.771	1.177	1.062–1.305
Teaching status	0.999	0.741–1.347	1.044	0.798–1.365
Comorbidity count	1.037	1.005–1.069	0.869	0.837–0.903
Charlson Index	0.809	0.771–0.849	0.741	0.680–0.809
Uninsured	1.494	1.077–2.073	0.463	0.294–0.729

(Continued)

**TABLE 3**  
(Continued)

Independent variables	COPD		LUNG CANCER	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
	Asthma		Congestive heart failure	
Coal production	0.999	0.996–1.003	1.000	0.999–1.001
County poverty rate	0.981	0.941–1.022	1.009	0.986–1.033
Social capital	0.898	0.554–1.453	0.823	0.604–1.121
Age	0.598	0.549–0.651	1.324	1.280–1.368
Female	2.536	2.010–3.199	1.028	0.963–1.098
Teaching status	0.855	0.617–1.183	0.757	0.591–0.970
Comorbidity count	0.898	0.875–0.923	1.119	1.096–1.143
Charlson Index	0.448	0.388–0.517	1.049	1.004–1.095
Uninsured	0.690	0.468–1.018	0.885	0.567–1.381

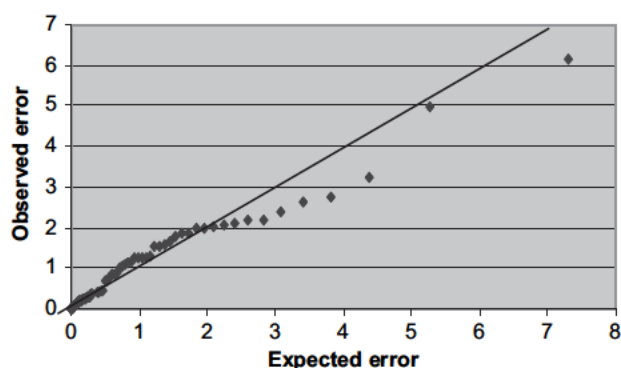


FIG. 1. Scatterplot showing observed and expected level 2 residuals for hypertension model.

The scatterplot of observed to expected model residuals was examined to determine whether the level 2 errors in the model were randomly distributed. Figure 1 shows that observed and expected errors are closely related. This figure is for the hypertension model, but the COPD model showed similar results. The correlation between observed and expected error in Figure 1 was .98.

## DISCUSSION

This is the first study to show that hospitalizations for COPD and hypertension are significantly elevated as a function of Appalachian coal production at the county level. The risk increases significantly as the volume of coal mining rises. The effects might be a result of exposure to PM associated with mining activities such as coal extraction and washing (Ghose & Banerjee, 1995), exposure to diesel particulate matter from operation of engines at mining sites (Monforton, 2006), or some interactive combination thereof.

Effects were not found for other conditions that were hypothesized to be sensitive to coal exposure, including kidney disease, lung cancer, and forms of heart disease. This might be due to exposure effects that are too weak to exert negative impacts on residents, limitations in the precision of the hospitalization data (discussed in more detail later), or time lags between exposure and illness. Exposure effects were not found for any of the potential insensitive conditions. These lists of sensitive and insensitive conditions are only a starting point for refined classifications as knowledge on this topic progresses.

Limitations of this study include the ecological design, which prohibits drawing a definitive causal link between the hospitalization event and coal mining activities. Adjustments were made for a set of demographic and county indicators, but it is possible that other unmeasured variables may contribute to poorer health in a way that is confounded with coal mining. Smoking and obesity, in particular, were not measured. However, the reverse finding for lung cancer suggests that coal production and smoking patterns are not confounded. Air pollution levels from industrial sources were also not measured, although power plants tend to be located in population centers and along major rivers, whereas primary coal mining locations often occur in separate, more rural areas. The weather patterns associated with a particular season might also affect both illness and volume of mining (i.e., a cold winter increases susceptibility to illness and increases economic demand for coal); this issue may be addressed in future research by examining effects for longer time intervals. The use of the proportional hospitalization indicator, like a proportional mortality ratio, has limitations (Miettinen & Wang, 1981; Decoufle et al., 1980), such as its dependence on the relative frequency of coal-sensitive to -insensitive conditions in the population.

The data are also limited by the geographic crudeness of the county measure: Some persons may live in a coal mining

county but some distance from the mining activities, while others live across county lines but closer to mining sites. Future research would be improved by obtaining a more refined geographic match between residence and coal mining activities; possibilities include secondary census tract data (e.g., Vassilev et al., 2001), or primary data collection studies with geographic information system (GIS) indicators. Unfortunately, the coal production figures for this study were not available on those smaller scales.

A significant limitation of the hospitalization data is that the county identified the location of the hospital, not necessarily the location where the patient resided. Persons who were transferred from other hospitals were excluded from analysis, but this is not a complete solution. To the extent that people move from one area to another for hospital care, this introduces error into the measurement. This error appear to be random rather than systematic, making detection of effects more difficult but not creating bias in the direction of effects. To make an argument for biased results due to patient mobility, one would have to argue that people differentially move from non-coal-mining areas to coal-mining areas for hospital care, for only COPD and hypertension and not for other conditions, and that this occurs relative to the intensity of mining. This particular pattern of movement seems unlikely. To the extent that error is random, with some patients moving into and out of coal producing areas for care, coal mining effects will be underestimated.

Another limitation of hospitalization data is that they are an indicator that is influenced by various other factors, including the quality of the ambulatory care system, and payer or geographic variation in diagnostic practices, in ways that could not be measured. COPD and hypertension in many cases are instances of ambulatory care-sensitive conditions. If the quality of outpatient care for these conditions is systematically poorer in coal mining areas, this might result in more frequent hospitalizations, but again, one would have to argue this poor quality phenomenon selectively for COPD and hypertension, when other ambulatory care-sensitive conditions, such as diabetes, showed no relationship to coal mining. Local diagnostic practice variations, such as distinctions between adult asthma and COPD, may also introduce error into estimates, as may differences due to type of payer.

The teaching status of the hospital was a variable that sometimes affected admission patterns. Teaching status likely interacts with mobility patterns, where patients with complex or serious illnesses are more likely to travel from their area of residence to a teaching hospital for specialty care. To the extent that teaching hospitals are located in urban areas where coal mining does not take place, this pattern may obscure possible coal-related effects. Lung cancer and kidney disease represent serious, complex illnesses, and hospitalization for these conditions was marginally higher as a function of teaching status ( $p < .10$ ), which may help to account for their nonsignificant links to coal mining. Hypertension and COPD, on the other hand, were related to less severe comorbidities and unrelated to

hospital teaching status, suggesting that these conditions are more likely to be treated at local hospitals near the patient's residence.

Despite the data limitations, which may be expected to dilute the magnitude of effects, effects were found for two health problems that are consistent with an exposure hypothesis. The inhalation of PM is associated with hypertension (Ibald-Mulli et al., 2001; Brook, 2005; Urch et al., 2005; Krewski et al., 2005) and COPD (Brabin et al., 1994; Coggon & Taylor, 1998) among miners and residents and in lab conditions. Individuals with hypertension show increased association between systemic inflammation and ambient PM<sub>2.5</sub> (particulate matter with a mass mean aerodynamic diameter  $\leq 2.5 \mu\text{m}$ ) (Dubowsky et al., 2006). The current study may be detecting the acute effects from residential exposure to PM at a certain time, or a chronic exposure effect that accumulates over time into increased risk of hospitalization. Other research has found that long-term exposure to ambient air pollution is related to higher incidence and mortality rates from cardiopulmonary disease and lung cancer (Miller et al., 2007; Krewski et al., 2005). Additional research using more refined methods will be necessary to isolate the nature and magnitude of the exposure effect. Future research may employ primary data collection efforts in targeted communities distal and proximal to coal mining activities to collect data on physiological measures and disease incidence for residents in these communities. Future studies need to clearly identify specific processes and pollutants that exert pathologic effects on local populations.

## CONCLUSIONS

The health consequences of exposure to mining activities reflect only a portion of the entire coal production and consumption cycle. Coal mining poses occupational hazards to miners (Scott et al., 2004), its burning contributes to air pollution and subsequent health hazards (Wellenius et al., 2006), and carbon emissions contribute to climate change with potential global health risks, including infectious epidemics, disruptions in the food chain, increased asthma prevalence, lung damage from ozone, and health consequences of floods and droughts (Patz et al., 2005; Bernard et al., 2001; Epstein, 2005). The health risks from residential proximity to mining present an additional negative consequence that results from reliance on this energy source.

If exposure effects are supported by further research, economic analyses of coal's contribution to domestic productivity may need to be revised to take into account the lost productivity and medical care costs linked to residential proximity to mining. Calculation of pollution levels in geographic areas may be developed to account for both the production and consumption of carbon-based energy. Implementation of national or state environmental and public health policies may be indicated to protect nearby citizens from mining by-product exposure.

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## Higher coronary heart disease and heart attack morbidity in Appalachian coal mining regions

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### ABSTRACT

**Background.** This study analyzes the U.S. 2006 Behavioral Risk Factor Surveillance System survey data ( $N=235,783$ ) to test whether self reported cardiovascular disease rates are higher in Appalachian coal mining counties compared to other counties after control for other risks.

**Methods.** Dependent variables include self reported measures of ever (1) being diagnosed with cardiovascular disease (CVD) or with a specific form of CVD including (2) stroke, (3) heart attack, or (4) angina or coronary heart disease (CHD). Independent variables included coal mining, smoking, BMI, drinking, physician supply, diabetes co morbidity, age, race/ethnicity, education, income, and others. SUDAAN Multilog models were estimated, and odds ratios tested for coal mining effects.

**Results.** After control for covariates, people in Appalachian coal mining areas reported significantly higher risk of CVD ( $OR=1.22$ , 95%  $CI=1.14-1.30$ ), angina or CHD ( $OR=1.29$ , 95%  $CI=1.19-1.39$ ) and heart attack ( $OR=1.19$ , 95%  $CI=1.10-1.30$ ). Effects were present for both men and women.

**Conclusions.** Cardiovascular diseases have been linked to both air and water contamination in ways consistent with toxicants found in coal and coal processing. Future research is indicated to assess air and water quality in coal mining communities in Appalachia, with corresponding environmental programs and standards established as indicated.

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Recent studies have documented poor population health outcomes in coal mining areas of Appalachia compared to other parts of the region or the nation (Hendryx, 2008, 2009; Hendryx and Ahern, 2008; Hendryx et al., 2008). These findings include higher chronic cardiovascular disease (CVD) mortality rates (Hendryx, 2009) and higher rates of self reported CVD (Hendryx and Ahern, 2008).

The risk for CVD is influenced by environmental, behavioral, genetic, demographic, and health services variables. (Galimanis et al., 2009; Marmot and Wilkinson, 2005). Risk behaviors, in turn, are related to lower socioeconomic status (SES); low SES persons are more likely to smoke, consume poor quality diets, and engage in sedentary lifestyles (Darmon and Drewnowski, 2008; Harwood et al., 2007; Marmot and Wilkinson, 2005; Woolf et al., 2006). Coal mining areas are characterized by lower SES relative to non mining areas (Halverson and Bischak, 2007; Hendryx, 2008; Wood, 2005), suggestive of higher CVD risk.

Environmental agents that contribute to CVD include arsenic, cadmium and other metals, non specific particulate matter (PM), and polycyclic aromatic hydrocarbons (PAHs) (Bhatnagar, 2006; Mastin, 2005; Miller et al., 2007). All of these agents are present in coal or introduced into local ambient environments via activities of coal

extraction and processing (Ghose, 2007; Kolker et al., 2006; McAuley and Kozar, 2006; WVGES, 2007).

Most previous research on population health in coal mining areas has employed county level mortality data rather than individual level data. An exception was a study of self reported chronic illness in relation to coal mining (Hendryx and Ahern, 2008); this study was limited to a non standard assessment instrument with limited individual level covariates in one state. The current study uses national Behavioral Risk Factor Surveillance System (BRFSS) data to assess CVD risk in coal mining areas before and after control for individual level covariates including smoking, obesity, co morbid diabetes, alcohol consumption and others. We test the hypothesis that CVD rates will be significantly elevated for residents of Appalachian coal mining counties after controlling for covariates, suggestive of an environmental impact. We also hypothesize that effects will be present for men and women, an indication that effects represent more than direct occupational exposure among male coal miners.

### Methods

#### Design

The study is a retrospective analysis of 2006 BRFSS (CDC, 2007a) data on CVD in relation to individual and county level risks, with a focus on Appalachian coal mining. The BRFSS collects data from random digit dialing telephone surveys of the non institutionalized U.S. civilian population aged

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18 and over. Surveys are conducted in all states and the District of Columbia by state health departments in cooperation with the Centers for Disease Control and Prevention (CDC). The 2006 BRFSS had a median response rate of 51%. However, the large sample size, coupled with comparisons between respondents and non respondents on key demographics indicate that non response is not a major problem (CDC, 2007b).

Appalachia is a mountainous region of the eastern United States that extends for more than 1000 miles from southern New York to northeastern Mississippi. It includes all of West Virginia and parts of 12 additional states, and has a population of more than 26 million people. Income levels are less than national averages, and poverty rates are chronically high especially in central Appalachia. (ARC, 2008) A map of the region may be found at [http://www.arc.gov/misc/arc\\_map.jsp](http://www.arc.gov/misc/arc_map.jsp).

## Data

Dependent variables include dichotomous self report measures assessing whether respondents were ever diagnosed with (1) angina or coronary heart disease (CHD), (2) heart attack or (3) stroke. A fourth general CVD category measured whether respondents reported the presence of any of these three CVD types. The morbidity categories are self reported so an exact correspondence to diagnostic categories is uncertain; Appendix A, however, provides a link between the self report measures and probable International Classification of Disease (ICD 10) diagnostic groupings.

Independent variables are taken from the 2006 BRFSS survey, the county level supplementary file provided by the CDC for the 2006 survey, the Energy Information Administration (EIA) (Freme, 2008), the Area Resource File, the US Census, and the Appalachian Regional Commission (ARC, 2007).

Covariates included smoking, coded as a three level variable: current, former (smoked at any time in the past), or lifetime non smoker. Self report

body mass index (BMI) was coded into: underweight (BMI < 18.5); normal (BMI 18.5 to < 25); overweight (BMI 25 to < 30); or obese (BMI 30 or greater) with the normal weight category serving as the referent. Alcohol consumption was coded as average number of drinks per day and was categorized into non drinker, light drinker (1 or fewer drinks per day), moderate drinker (more than 1 but less than 4), or heavy drinker (4 or more per day). Light drinkers were used as the referent category.

Age was coded in years and ranged from 18 to 99. Diabetes co morbidity was coded yes/no based on the respondent reporting ever being diagnosed with diabetes. Race/ethnicity was coded as dichotomous variables specifying African American, Native American, non white Hispanic, Asian American, or White. Marital status was dichotomized as married or cohabitating versus any other status. Annual household income was coded as an eight level variable from "less than \$10,000" to "\$75,000+". Education was scored 1 to 6, ranging from "never attended school or only kindergarten" to "college 4 years or more (college graduate)"; a score of 4 was equivalent to a high school graduate. Metropolitan status was scored 1 to 5 with higher scores indicating a more rural environment, ranging from "in the center city of a metropolitan statistical area (MSA)" to "not in an MSA". A final BRFSS variable was the county level 2005 supply of office based, general practice MDs per 100,000 persons.

The EIA was used to identify coal mining counties (Freme, 2008), defined as a county with any amount of coal mining over the years 1996–2006. Designations established by the ARC (2007) for 2006 were used to identify Appalachian counties. Then, a four category variable was created to classify each county nationwide as Appalachian (yes/no) and coal mining (yes/no). Area Resource File data were used to find county population density measured as persons per square land mile, and US Census data were used for the percent of households receiving drinking water from private wells.

**Table 1**  
Summary of 2006 study variables by county group, including Appalachia (yes/no) and coal mining (yes/no).

	County group				Total
	Appalachia, coal mining	Appalachia, no coal mining	Not Appalachia, coal mining	Not Appalachia, no coal mining	
N	9330	9622	9089	207,742	235,783
Number of counties	60	90	42	956	1148
% with any CVD <sup>a</sup>	14.4	12.0	9.2	10.0	10.2
% with angina or CHD <sup>b</sup>	8.7	7.0	5.3	5.7	5.8
% with heart attack	7.6	6.3	4.5	5.1	5.2
% with stroke	4.5	3.6	3.0	3.3	3.3
% female	61.0	59.8	59.2	59.5	59.6
Smoking status					
% Current	24.6	22.7	17.9	18.9	19.2
% Former	27.0	26.0	29.0	29.3	29.0
% Not a smoker	48.5	51.4	53.1	51.9	51.8
Alcohol use in last 30 days					
% None	58.4	61.4	46.2	46.1	47.2
% Light	34.9	32.6	45.4	45.1	44.2
% Moderate	6.0	5.5	7.7	8.2	8.0
% Heavy	0.7	0.6	0.5	0.7	0.7
% with diabetes	12.1	11.4	9.4	9.3	9.5
% High school education	64.0	58.3	56.1	54.5	55.1
% College education	24.0	29.5	37.4	37.4	36.5
% Married	55.9	60.9	59.9	58.7	58.7
Race/ethnicity					
% African American	3.9	7.2	3.8	8.7	8.2
% Native American	2.3	3.1	7.3	8.4	7.9
% Asian American	1.2	1.9	6.8	3.8	3.8
% Hispanic	1.2	2.0	5.3	6.5	6.1
BMI <sup>c</sup> category					
% Underweight	1.4	1.5	1.4	1.6	1.6
% Overweight	36.6	36.5	36.4	36.6	36.6
% Obese	30.5	28.6	26.0	25.8	26.1
Mean (SD), <sup>d</sup> income category	5.0 (2.2)	5.3 (2.2)	5.8 (2.1)	5.7 (2.1)	5.7 (2.1)
Mean (SD), education category	4.6 (1.0)	4.7 (1.1)	5.0 (1.0)	4.9 (1.0)	4.9 (1.1)
Mean (SD), age	52.7 (16.5)	52.1 (15.9)	51.3 (16.5)	51.7 (16.4)	51.7 (16.4)
Mean (SD), metropolitan status category	2.8 (1.4)	3.0 (1.7)	2.6 (1.7)	2.5 (1.6)	2.5 (1.5)
Mean (SD), MDs per 100,000	24.3 (7.8)	31.1 (12.3)	37.0 (12.9)	27.1 (12.6)	27.5 (12.7)

<sup>a</sup> CVD: cardiovascular disease.

<sup>b</sup> CHD: coronary heart disease.

<sup>c</sup> BMI: Body Mass Index.

<sup>d</sup> SD: Standard deviation.

**Table 2**

Unadjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by Appalachia and coal mining group, 2006.

	Appalachia, coal mining, OR (95% CI)	Appalachia, no coal mining, OR (95% CI)	Not Appalachia, coal mining, OR (95% CI)
Any CVD <sup>a</sup>	1.52 (1.44, 1.62)**	1.23 (1.15, 1.31)**	0.91 (0.85, 0.98)*
Angina or CHD <sup>b</sup>	1.59 (1.48, 1.72)**	1.26 (1.16, 1.36)**	0.93 (0.85, 1.02)
Heart attack	1.53 (1.41, 1.66)**	1.25 (1.14, 1.36)**	0.88 (0.79, 0.97)*
Stroke	1.37 (1.24, 1.52)**	1.09 (0.97, 1.21)	0.89 (0.79, 1.01)

Non-mining, non-Appalachian counties serve as the referent group.

<sup>a</sup> CVD: cardiovascular disease.

<sup>b</sup> CHD: coronary heart disease.

\*  $p < .02$ .

\*\*  $p < .0001$ .

### Analysis

Analyses included descriptive summaries followed by inferential analyses to examine CVD risk in coal mining areas. Models used SUDAAN Proc Multilog to account for the complex sampling design, before and after control for covariates. Models with covariates were also estimated separately by gender. Counties without mining and outside Appalachia served as the referent group for the mining variable. Variations between Appalachian and non-Appalachian mining regions in population density, and in the percent of households using well water, were subject to unpaired *t* tests for group differences.

### Results

We included only persons in the 50 states and the District of Columbia ( $N = 298,908$ .) Missing BRFSS data reduced the final sample

to 235,783 primarily due to missing income data (missing in 43,354 cases). There are 3141 US counties nationwide; 1148 (37%) are represented in the study. There are 410 Appalachian counties based on 2006 ARC designations and 150 (37%) are represented in the study; similarly, there are 139 Appalachian counties with coal mining, and 60 (43%) are represented.

Table 1 provides a summary of study variables overall and by the four county groups. Appalachian counties were characterized by higher smoking rates, lower alcohol consumption, and higher CVD rates. They had lower education and income levels, and had on average older populations. In general, these differences were more pronounced in coal mining portions of Appalachia compared to non mining portions of the region.

Before adjusting for covariates, the odds of reporting CVD, overall and for each type, were significantly higher in Appalachian coal mining areas relative to non-Appalachian, non mining locations (Table 2). Effects for non mining Appalachian areas were detected for overall CVD, heart attack, and CHD, but not for stroke. Coal mining areas outside of Appalachia had significantly lower risk of total CVD and heart attack.

After covariate adjustment, risk remained significantly elevated in coal mining areas of Appalachia for overall CVD, angina or CHD, and heart attack, but not stroke (Table 3). Risk for angina or CHD remained significantly elevated in non mining portions of Appalachia, but other forms of CVD did not. People in non-Appalachian mining areas reported significantly lower risk of heart attack. Odds ratios (ORs) were highest for the Appalachian mining counties. After adjusting for covariates, the Appalachian mining area effects remained significant ( $p < 0.0001$ .) Most other independent variables were significantly related to CVD risk in expected ways including greater age, over

**Table 3**

Full model adjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by county group including Appalachia (yes/no) and coal mining (yes/no), 2006.

	Any CVD <sup>a</sup>	Angina or CHD <sup>b</sup>	Heart attack <sup>c</sup>	Stroke <sup>d</sup>
<i>County category</i>				
Non-mining, non-Appalachian	1.00	1.00	1.00	1.00
Appalachian coal-mining	1.21 (1.13, 1.30)**	1.28 (1.18, 1.39)**	1.20 (1.10, 1.31)**	1.05 (0.94, 1.17)
Appalachian non-mining	1.07 (1.01, 1.15)*	1.12 (1.03, 1.22)*	1.07 (0.98, 1.18)	0.93 (0.82, 1.04)
Coal mining, non-Appalachian	0.95 (0.88, 1.03)	0.97 (0.87, 1.07)	0.91 (0.81, 1.01)	0.93 (0.82, 1.06)
Female	0.57 (0.55, 0.58)	0.56 (0.54, 0.58)	0.44 (0.42, 0.45)	0.78 (0.74, 0.82)
Smoking status	1.43 (1.40, 1.46)	1.40 (1.37, 1.44)	1.53 (1.49, 1.57)	1.37 (1.32, 1.41)
<i>Alcohol use categories</i>				
Light drinker	1.00	1.00	1.00	1.00
Non-drinker	1.34 (1.29, 1.38)	1.31 (1.25, 1.36)	1.36 (1.30, 1.42)	1.44 (1.36, 1.53)
Moderate drinker	0.85 (0.79, 0.90)	0.89 (0.82, 0.96)	0.80 (0.73, 0.87)	0.84 (0.75, 0.95)
Heavy drinker	1.00 (0.83, 1.20)	0.88 (0.68, 1.12)	1.05 (0.83, 1.32)	1.24 (0.93, 1.65)
Diabetes	2.25 (2.17, 2.34)	2.21 (2.11, 2.31)	2.22 (2.12, 2.32)	1.95 (1.84, 2.07)
Education	0.97 (0.96, 0.99)	1.02 (1.00, 1.04)	0.95 (0.93, 0.97)	1.00 (0.97, 1.02)
Married	1.08 (1.04, 1.12)	1.17 (1.12, 1.22)	1.08 (1.03, 1.13)	1.03 (0.98, 1.09)
African American	0.94 (0.89, 0.99)	0.73 (0.68, 0.79)	0.88 (0.81, 0.94)	1.17 (1.08, 1.27)
Native American	1.34 (1.21, 1.48)	1.29 (1.14, 1.46)	1.30 (1.14, 1.48)	1.39 (1.19, 1.61)
Asian American	0.98 (0.90, 1.07)	0.89 (0.80, 1.00)	1.01 (0.91, 1.13)	1.17 (1.03, 1.33)
Hispanic	0.61 (0.54, 0.69)	0.62 (0.54, 0.73)	0.64 (0.54, 0.75)	0.60 (0.49, 0.72)
<i>BMI<sup>e</sup> categories</i>				
BMI normal	1.00	1.00	1.00	1.00
BMI underweight	1.32 (1.17, 1.48)	1.00 (0.85, 1.17)	1.37 (1.18, 1.60)	1.49 (1.27, 1.75)
BMI overweight	1.26 (1.21, 1.31)	1.32 (1.26, 1.38)	1.27 (1.21, 1.33)	1.09 (1.03, 1.15)
BMI obese	1.58 (1.52, 1.65)	1.75 (1.66, 1.84)	1.59 (1.50, 1.67)	1.23 (1.15, 1.31)
Income scale	0.86 (0.85, 0.87)	0.88 (0.87, 0.89)	0.87 (0.86, 0.88)	0.82 (0.81, 0.83)
Age	1.06 (1.06, 1.06)	1.06 (1.06, 1.06)	1.06 (1.06, 1.06)	1.05 (1.05, 1.05)
Metropolitan status	1.01 (1.00, 1.02)	1.02 (1.00, 1.03)	1.01 (1.00, 1.02)	0.99 (0.98, 1.01)
Physician supply	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)

<sup>a</sup> CVD: cardiovascular disease. Model Satterthwaite adjusted chi-square = 71,454 ( $df = 23$ ),  $p < 0.00001$ .

<sup>b</sup> CHD: coronary heart disease. Model Satterthwaite adjusted chi-square = 69,870 ( $df = 23$ ),  $p < 0.00001$ .

<sup>c</sup> Model Satterthwaite adjusted chi-square = 65,516 ( $df = 23$ ),  $p < 0.00001$ .

<sup>d</sup> Model Satterthwaite adjusted chi-square = 62,537 ( $df = 23$ ),  $p < 0.00001$ .

<sup>e</sup> BMI: Body mass index.

\*  $p < 0.05$ .

\*\*  $p < 0.0001$ .

**Table 4**  
Unadjusted % with cardiovascular disease for men and women, and adjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by Appalachia and coal mining groups, separately for women and men, 2006.

	Appalachia, coal mining		Appalachia, no coal mining		Not Appalachia, coal mining		Not Appalachia, no coal mining	
	Unadjusted % with CVD <sup>a</sup>	OR (95% CI)	Unadjusted % with CVD <sup>a</sup>	OR (95% CI)	Unadjusted % with CVD <sup>a</sup>	OR (95% CI)	Unadjusted % with CVD <sup>a</sup>	OR
<b>Women (N = 140,444)</b>								
Any CVD <sup>a</sup>	12.7	1.18 (1.08, 1.29)**	9.9	0.99 (0.90, 1.10)	8.5	1.04 (0.93, 1.16)	8.4	1.00
Angina or CHD <sup>b</sup>	7.5	1.25 (1.12, 1.39)***	5.9	1.11 (0.98, 1.26)	4.6	1.05 (0.91, 1.20)	4.5	1.00
Heart attack	5.9	1.17 (1.03, 1.32)*	4.4	0.98 (0.85, 1.12)	3.7	1.03 (0.89, 1.20)	3.7	1.00
Stroke	4.5	1.07 (0.93, 1.23)	3.2	0.82 (0.70, 0.96)*	3.1	0.98 (0.83, 1.16)	3.2	1.00
<b>Men (N = 95,339)</b>								
Any CVD <sup>a</sup>	17.1	1.25 (1.13, 1.38)***	15.0	1.17 (1.05, 1.29)**	10.2	0.85 (0.76, 0.97)*	12.2	1.00
Angina or CHD <sup>b</sup>	10.7	1.31 (1.17, 1.48)***	8.7	1.12 (0.99, 1.27)	6.3	0.89 (0.77, 1.03)	7.3	1.00
Heart attack	10.3	1.22 (1.08, 1.38)**	9.0	1.16 (1.03, 1.31)*	5.6	0.81 (0.69, 0.94)*	7.1	1.00
Stroke	4.4	1.02 (0.86, 1.21)	4.2	1.08 (0.91, 1.29)	2.8	0.86 (0.70, 1.06)	3.4	1.00

Non-mining, non-Appalachian counties serve as the referent group.

<sup>a</sup> CVD: cardiovascular disease.

<sup>b</sup> CHD: coronary heart disease.

\*  $p < 0.02$ .

\*\*  $p < 0.003$ .

\*\*\*  $p < 0.0001$ .

weight and obesity, smoking, diabetes, lower education, and lower income.

Persons who reported no alcohol use were at higher risk relative to light drinkers, while moderate drinkers reported lower risk. The OR for heavy drinking was not significant. An additional analysis of total CVD included only age and the drinking categories; in this analysis (results not shown), both heavy drinking and non drinking were significantly related to higher CVD risk relative to light drinking, while moderate drinking was not significantly different.

When the Multilog models with covariates were repeated separately by gender there were significant Appalachian coal mining effects for women and men for total CVD, angina or CHD, and heart attack. Table 4 shows adjusted odds ratios for the mining variable separately by gender but does not include the detailed findings for the other covariates. This table also shows the unadjusted or crude percent of women and men with CVD by county group.

Population density was significantly higher in Appalachian coal mining counties (118.8 persons per square mile) relative to non Appalachian mining counties (56.7 persons per square mile),  $t = 3.77$ ,  $p < 0.0002$ . The percent of households relying on private wells versus treated water systems was also higher in Appalachian versus non Appalachian mining areas, 30.1% and 17.8 %, respectively;  $t = 6.37$ ,  $p < 0.0001$ .

## Discussion

This study documents higher CVD morbidity for men and women in coal mining portions of Appalachia that persist after control for age, smoking, BMI, alcohol consumption, SES, and other established risks. The results suggest that environmental pollution from coal mining may be a contributing factor to population prevalence of CVD morbidity above documented Appalachian health disparities linked to behavioral and socioeconomic risks.

Coal mining effects were specific to Appalachian mining areas and were not found for mining in other parts of the country. This might reflect unmeasured confounds unique to the Appalachian population or culture that increase CVD risk. But the results might also reflect differences in environmental exposures. The population density of Appalachian coal mining areas is greater than in other coal mining regions, thereby increasing exposure potential. People live in "hollows" or narrow valleys in close proximity to mining activities in Appalachia; the topography in combination with climate and population density may serve to concentrate ambient PM or ground water exposure. Appalachian coal mining populations were also found

to be significantly more reliant on private well water compared to the non Appalachian mining population, and so may be more exposed to contamination from mining activity that impacts ground water.

Appalachian mining related CVD effects are present for women and men, evidence that the effects cannot be attributed only to direct occupational exposure. However, the adjusted odds ratios are higher for men than for women (although these differences are not statistically significant), indicating that differential occupational exposure may have some impact on observed effects. There is also a CVD effect for men in non mining portions of Appalachia, which might reflect behavioral risks unique to men in Appalachia, or commuting patterns which take male workers across county lines from non mining to mining locations. Finally, men in mining areas outside Appalachia have lower CVD morbidity; we speculate that this might reflect a "healthy worker" effect or other unique demographic or behavioral characteristics of men who live in mining areas outside Appalachia.

An adjusted Appalachian mining effect was present for overall CVD and for heart attack and angina/CHD, but not for stroke. Reasons for the non significant stroke findings are unclear but may be related to the acute nature of stroke, to the concentration of this event in older populations, or to higher levels of stroke lethality in Appalachian mining areas. Exposure to air pollution is related to increased stroke risk, but this effect seems to be particular to acute exposure episodes (Lokken et al., 2009; Szyszkowicz, 2008). Previous research on the topic of population health in coal mining areas has documented stronger mining effects for chronic forms of illness rather than acute illness (Hendryx, 2009; Hendryx and Ahern, 2008). Stroke may also be more highly dependent on age or other sociodemographic variables that overpower the relatively smaller effects of contaminants from the mining industry for this particular illness event.

Study limitations include the lack of direct environmental quality data, and the cross sectional design. Longitudinal assessments of CVD development in relation to mining exposure are warranted. The results suggest the need for environmental assessments to confirm whether these associations are the result of pollution from the mining industry. There is evidence from other sources, however, that air and water quality are impaired around coal mining activity in Appalachia or elsewhere. (Ghose and Majee, 2007; McAuley and Kozar, 2006). The finding that non drinking was related to higher CVD risk does not necessarily mean that drinking is protective; persons diagnosed with CVD may subsequently choose to stop drinking as a health protection behavior.

The survey was conducted in 2006 and coal mining was measured for the years 1996–2006. The environmental impact on the development of CVD occur over the long term (Ferrellecio et al., 2000; Miller

et al., 2007; Pope et al., 2002), but some effects may be more immediate (Wellenius et al., 2006). A mining county in 1 year is almost always a mining county in other or all other years (Freme, 2008) so 1996–2006 is (1) a reasonable proxy of mining in 2006 and (2) appropriate to include to the extent that environmental mining effects are delayed.

Because the BRFSS data are based on self report, people who reported they had experienced a heart attack or stroke had to have survived it. If people in isolated Appalachian areas who experienced these events were more likely to die from them, mining related effects could be underestimated. This is a possible explanation for the lack of a mining effect for the stroke variable. Previous research has documented higher mortality rates for CVD in mining areas (Hendryx, 2009).

The results of this study and others that document mining related health disparities have implications for environmental policy as disease prevention. For example, the West Virginia Department of Environmental Protection (DEP) maintains 22 air monitoring stations that assess standard ambient air quality indicators including PM<sub>2.5</sub>, ozone, sulfur dioxide and others (Benedict, 2008). These stations are located in 13 of West Virginia's 55 counties; none of the monitors are located in communities that are defined primarily by coal mining activity. Establishing new monitoring stations in coal mining towns would be one policy initiative to address environmental quality in coal mining locations.

More comprehensive assessments of water quality may also be undertaken. Using West Virginia as an example again, the current protocol for well water testing is that routine DEP tests occur in response to citizen requests, but tests are limited to bacteriological screens, not metals or compounds. Another environmental policy change would include tests for metals and compounds when residents express concerns for well water quality that may be impacted by mining activity. These recommendations pertain not only to West Virginia but other mining communities where impaired air and water quality adversely impact human health.

Finally, regardless of the relative impacts of environmental, behavioral or socioeconomic factors on CVD, the results document that the geographic areas of Appalachia where CVD is highest are in the coalfields. To achieve the stated objective of the National Institutes of Health to reduce and eliminate disparities in Appalachia relative to the nation (Zerhouni and Ruffin, 2002), disease prevention efforts should be focused on coal mining portions of the region.

**Conflict of interest statement**  
None.

## Appendix A

List of approximate International Classification of Disease (ICD 10) codes corresponding to self reported morbidity categories on the 2006 Behavioral Risk Factor Surveillance System (BRFSS).

Self-reported morbidity	Approximate corresponding ICD-10 codes
Angina or coronary heart disease	I20, I24, I25
Heart attack	I21, I22
Stroke	I60–I64

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# Mortality Rates in Appalachian Coal Mining Counties: 24 Years Behind the Nation

Michael Hendryx

## ABSTRACT

Appalachia has higher morbidity and mortality compared to the nation, and suffers greater socioeconomic disadvantages. This article investigates the relationship of coal mining to elevated mortality rates in Appalachia. Total mortality rates for the years 1999–2004 were investigated in a national county-level analysis that included coal mining as the primary independent variable. Counties in Appalachia where coal mining is heaviest had significantly higher age-adjusted mortality compared to other Appalachian counties and to other areas of the country. Elevated mortality rates persisted in Appalachian coal mining areas after further statistical adjustment for smoking, poverty, education, rural-urban setting, race/ethnicity, and other variables. After adjustment for all covariates, Appalachian coal mining areas were characterized by 1,607 excess annual deaths over the period 1999–2004. Adjusted mortality rates increase with increasing coal production from 1 to 7 million tons. These findings highlight environmental inequities that persist in Appalachian coal mining areas. Reducing these inequities will require development of alternative economies and promotion of environmental justice through regulatory and allocative policy changes.

APPALACHIA HAS LONG been characterized by social inequalities and health disparities.<sup>1–4</sup> Recently, the contributions that the coal mining industry makes to these inequalities and disparities has come under closer attention. Coal mining areas are linked to higher population hospitalization rates for some cardiovascular and respiratory conditions,<sup>5</sup> and to higher reported rates of some forms of chronic illness and poorer reported health status.<sup>6</sup> Compared to other parts of Appalachia, coal mining areas are also characterized by poor socioeconomic conditions including higher levels of poverty and lower education rates.<sup>7</sup>

The purpose of the current study was to extend prior research on the community health impacts of the Appalachian coal mining industry through an examination of mortality rates. The study tests whether mortality rates are elevated in Appalachian coal mining areas, and whether elevated mortality, if found, is due solely to socioeconomic conditions or if an additional effect specific to coal mining persists. The study also examines temporal trends in mortality in coal mining areas. Three hypotheses are tested:

1. Coal mining areas of Appalachia will be associated with higher total mortality rates compared to the rest of Appalachia and the nation, both before and after adjustment for socioeconomic covariates.
2. Mortality rates will be higher in Appalachia compared to the nation, but these rates will not remain elevated after controlling for socioeconomic effects.
3. Elevated mortality in Appalachian coal mining areas will be present over the time period 1979 to 2004.

## METHODS

### *Design*

The study is a retrospective investigation of national mortality rates for the years 1979–2004. The level of analysis is the county ( $N = 3,141$ ; missing data on covariates reduced the sample by 61 cases for regression analyses). The study is an analysis of anonymous, secondary data sources and meets university Internal Review Board standards for an exception from human subjects review.

### *Data*

Mortality data were obtained from the Centers for Disease Control & Prevention (CDC) measuring county-level mortality rates per 100,000, age-adjusted using the 2000

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US standard population.<sup>8</sup> Total mortality rates were examined for all internal causes, excluding causes from external factors (homicide, suicide, motor vehicle accidents, other accidents.) All ages were included. Analyses for hypotheses 1 and 2 use mortality figures for the years 1999–2004 combined, and analysis of hypothesis 3 uses annual mortality figures for the years 1979 through 2004.

Coal production data were obtained from the Energy Information Administration (EIA)<sup>9–14</sup> measured as tons of coal mined in every county each year for the years 1999–2004. Levels of coal mining were not normally distributed across counties. To estimate exposure, two primary analyses were conducted. The first examined mortality based on dividing counties across the country into four groups: Appalachian counties with no coal mining, Appalachian counties with coal mining up to four million tons combined over the six years 1999–2004, Appalachian counties with coal mining greater than four million tons, and other counties in the nation with no coal mining (104 non-Appalachian counties where coal mining took place were deleted from the analysis.) The choice of 4 million tons divided Appalachian coal mining counties approximately in half, with 65 Appalachian counties mining less than 4 million tons over these years, and 67 with more than 4 million tons. The second method estimated per capita exposure, found by dividing county tons mined by the county population from the 2000 Census; counties were grouped into four levels: no mining in Appalachia, per capita exposure up to 200 tons per person, per capita exposure greater than 200 tons, and no mining in the rest of nation (used as the referent).

A series of supplementary analyses were conducted to test for the robustness of findings across alternative specifications of coal mining. One set of analyses examined coal mining effects when the higher category of coal mining was based on integer levels from one to seven million tons. A second set correspondingly examined per capita exposure effects at 50-ton increments from 50 to 400 tons per capita. A third set examined whether differences in mortality rates were related to surface mining versus underground mining. A fourth set examined whether mortality rates in coal mining areas were elevated only in Appalachian coal mining areas or in coal mining areas throughout the nation.

Coal production figures for years prior to 1999 are not readily available for all counties, therefore, tests of hypotheses 1 and 2 were constrained to mortality rates from the period 1999 to 2004. There is, however, considerable historical evidence that Appalachian counties characterized by heavy coal mining during recent years were also heavy coal mining areas in previous years and decades, simply as a consequence of the presence of economically minable coal in these areas.<sup>15–18</sup> Therefore, the test of hypothesis 3 examined historical mortality rates from 1979 to 2004, using coal production data from 1999–2004 to identify heavy coal mining counties in Appalachia.

Data on covariates were obtained from the 2005 Area Resource File,<sup>19</sup> CDC Behavioral Risk Factor Surveillance System (BRFSS),<sup>20</sup> and the Appalachian Regional Commission.<sup>21</sup> Selection of covariates was based on previously

identified risk factors or correlates of elevated mortality.<sup>22–32</sup> Covariates included smoking rates; percent male population; percent of the population with college and high school education; poverty rates; race/ethnicity rates (percent of the population who were African American, Native American, Non-white Hispanic, Asian American, using White as the referent category in regression models); percent without health insurance; physician supply (number of active MDs and DOs per 1,000 population); rural-urban continuum codes grouped into metropolitan, micropolitan, and rural; Southern state (yes or no, South equal to Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia); and Appalachian county (yes or no as defined by the 417 counties or independent cities in 13 states recognized by the Appalachian Regional Commission). CDC smoking rates were available for states and some county-based metropolitan areas; the state average was used when the specific county rate was not available.

### Analysis

Analyses were conducted using bivariate correlations, general linear models and ordinary least squares multiple regression models to test for the association between coal mining and mortality, without and with control for covariates.

## RESULTS

Table 1 shows total age-adjusted mortality rates for the four groups of counties before adding covariates. Mortality rates were highest in heavy coal mining areas of Appalachia, and were lowest in non-coal mining areas outside Appalachia. Other areas of Appalachia, either without mining or with lower levels of mining, had intermediate mortality rates.

Bivariate correlations were examined to test for multicollinearity among independent variables. The county poverty rate was highly correlated to percent of the population without health insurance ( $r = .82$ ); therefore, the insurance variable was dropped from further analysis.

Table 2 shows multiple regression results that consider effects of covariates on mortality. Results for each model specification, total tons or tons per capita, were almost identical. Appalachian counties with lower levels of mining were not associated with differences in mortality, but counties characterized by high levels of coal mining had significantly higher mortality after accounting for effects of age, smoking, poverty, education, race/ethnicity, rural-urban setting and other measures. Higher mortality was also predicted independently from smoking, lower education, poverty, African American or Native American race, living in the South, and urban setting. A greater supply of physicians was related to higher mortality. A greater percentage Hispanic population was related to lower mortality. The Table 1 and Table 2 findings support the first two study hypotheses.

Based on the 2000 US Census, the population of Ap-

TABLE 1. AGE-ADJUSTED MORTALITY PER 100,000 FOR 1999–2004 BY COUNTY TYPE<sup>1</sup>

<i>Appalachian coal-mining ≥4 million tons</i>	<i>Appalachian coal-mining &lt;4 million tons</i>	<i>Other Appalachian</i>	<i>Rest of nation</i>
950.2 a	890.7 b	884.1 b	820.2 c

<sup>1</sup>Model F = 53.67 (df = 3, 2,973),  $p < 0.0001$ . Letters a, b, and c indicate means significantly different at  $p < 0.05$  using post-hoc Ryan-Einot-Gabriel Welsch multiple range test.

palachian counties where mining exceeded 4 million tons was 3,883,143. The age-adjusted death rate in coal mining areas compared to non-Appalachian, non-mining counties before covariate adjustment translates to 5,048 excess annual deaths in Appalachian coal mining areas for the years 1999–2004. After covariate adjustment, the coefficient (41.39) for the mining effect measured in tons translates to 1,607 excess annual deaths in Appalachian coal mining areas.

To examine the stability of effects at different defined levels of “high” coal mining, the regression models were repeated with all covariates for integer levels of high coal mining from 1 to 7 million tons, along with a model where Appalachia was included but the coal mining variables were not (see Figure 1). High levels of coal mining were significant at all levels, but the effect for Appalachia without coal mining was not. Furthermore, the coefficient for the coal mining effect increased from 1 to 5 million tons

before leveling off, suggesting a dose-response effect up to the 5 million ton level, beyond which the smaller number of counties meeting the definition of high mining suggests possible statistical power problems (N = 49 counties at 7 million tons). Even at one million tons, the estimated number of deaths was substantially higher than the estimate for the Appalachian region in general before inclusion of coal mining into the model. (Results are not shown for the corresponding tests of per capita exposure, but were significant at all levels from 50 to 400 tons, and the magnitude of the coefficient increased with increasing exposure.)

Models were also run separately for surface mining and underground mining, both within Appalachia and nationwide. Coal mining effects were significant for Appalachia and the combined analysis for both underground and surface mining, but not for coal-mining limited to ar-

TABLE 2. MULTIPLE REGRESSION RESULTS TO PREDICT 1999–2004 AGE-ADJUSTED MORTALITY

<i>Variable</i>	<i>Coal mining measured in tons</i>			<i>Coal mining measured in tons per capita</i>		
	<i>Unstandardized coefficient</i>	<i>Standard error</i>	<i>p&lt;</i>	<i>Unstandardized coefficient</i>	<i>Standard error</i>	<i>p&lt;</i>
Intercept	783.5	57.7	0.0001	785.2	57.7	0.0001
Coal mining <4 million tons	1.50	11.59	0.90	—	—	—
Coal mining ≥4 million tons	41.39	11.69	0.0004	—	—	—
Coal mining <200 tons per capita	—	—	—	8.58	10.82	0.43
Coal mining ≥200 tons per capita	—	—	—	40.76	12.69	0.0013
Appalachian region (no coal mining)	−3.16	5.99	0.60	−3.02	6.00	0.62
Smoking rate	4.70	0.54	0.0001	4.69	0.54	0.0001
Metropolitan county	51.66	4.20	0.0001	51.64	4.20	0.0001
Micropolitan county	21.47	4.14	0.0001	21.54	4.14	0.0001
Percent male	0.03	0.87	0.97	0.03	0.87	0.98
Primary care physicians per 1000	4.76	1.43	0.0009	4.79	1.43	0.0008
South region	29.10	5.05	0.0001	29.04	5.06	0.0001
Poverty rate	6.55	0.52	0.0001	6.56	0.52	0.0001
Percent African American	1.53	0.16	0.0001	1.54	0.16	0.0001
Percent Native American	1.90	0.24	0.0001	1.90	0.24	0.0001
Percent Hispanic	−1.75	0.17	0.0001	−1.72	0.17	0.0001
Percent Asian American	−0.90	0.80	0.26	−0.90	0.80	0.26
High school education rate	−1.79	0.41	0.0001	−1.77	0.41	0.0001
College education rate	−3.24	0.36	0.0001	−3.25	0.36	0.0001

<sup>1</sup>Model adjusted  $R^2 = 0.54$ ; F = 219.7 (df = 16, 2,959),  $p < 0.0001$ .

<sup>2</sup>Model adjusted  $R^2 = 0.54$ ; F = 219.3 (df = 16, 2,959),  $p < 0.0001$ .

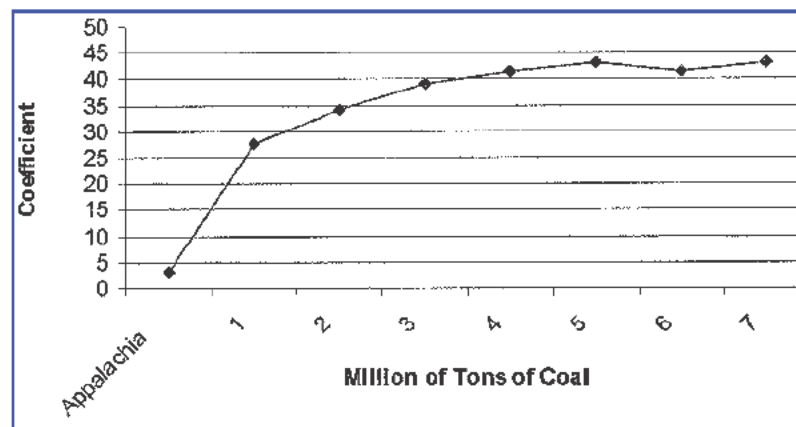


FIG. 1. Mortality per 100,000 in high Appalachian coal mining areas, 1999–2004, adjusting for all covariates, by level of mining. Appalachia refers to the effect of the Appalachia regional variable without consideration of coal mining. The Appalachia variable was not significant but all levels if mining were at  $p < .009$  or better.

eas outside Appalachia (the analysis of non-Appalachian coal mining effects deleted Appalachian coal mining counties). Results are summarized in Table 3.

As the test of hypothesis 3, total age-adjusted mortality rates for the years 1979 to 2004 are shown in Figure 2 for three groups: Appalachian counties with coal mining  $\geq 4$  million tons, other Appalachian counties (either no mining or mining less than 4 million tons), and other counties in the nation. Mortality rates are significantly different across time ( $p < .0001$ ), county type ( $p < .0001$ ), and the time-county interaction ( $p < .002$ ). Rates decline significantly over time for all groups, but are consistently highest for high coal mining areas of Appalachia. Compared to 1979, the mortality rates for 2004 were 13.3% lower in coal mining areas, 11.2% lower for other areas of Appalachia and 15.3% lower for the rest of the country; that is, the rate of decline was less for Appalachia and coal mining areas compared to the nation. Mortality rates for coal mining areas in 2004 are about the same as those for counties outside of Appalachia from 1980.

## DISCUSSION

Results show that higher mortality in Appalachia is due to poverty, smoking, poor education, and race-related effects. Once these factors are accounted for, non-coal mining areas of Appalachia have death rates no different than the rest of the country. Coal mining areas, however, show

elevated age-adjusted mortality both before and after adjustment for covariates. This is the case when Appalachian coal mining is the focus, but not for coal mining areas outside of Appalachia. Age-adjusted mortality rates for Appalachian coal mining areas lag about 24 years behind national rates outside Appalachia.

Causes of elevated mortality in coal mining areas may reflect behavioral, cultural, and economic factors only partly captured through available covariates, but may also reflect environmental contamination from the coal mining industry. That effects were found for Appalachian coal mining areas but not coal mining areas elsewhere may reflect the unique relationship of mining activity to topography and population centers characteristic of Appalachia. Coal mining is a major industrial activity in eight Appalachian states.<sup>33</sup> Mountaintop removal mining methods have become more prevalent in Appalachia, and often occur close to population centers; in West Virginia, surface mining constituted 42% of total mining tonnage in 2006, compared to 19% in 1982.<sup>34</sup> Coal contains mercury, lead, cadmium, arsenic, manganese, beryllium, chromium, and many other toxic and carcinogenic substances<sup>35</sup> and the mining and preparation of coal at local processing sites releases tons of annual ambient particulate matter and contaminates billions of gallons of water.<sup>36–38</sup> Coal preparation involves crushing coal into smaller particles, mixing coals of different qualities prior to sale, transporting coal via truck and rail, and remov-

TABLE 3. ADJUSTED REGRESSION COEFFICIENT FOR THE HIGH COAL MINING VARIABLE ( $\geq 4$  MILLION TONS), BY MINING TYPE (SURFACE, UNDERGROUND, AND COMBINED), AND BY INCLUSION OR EXCLUSION OF NON-APPALACHIAN COAL MINING AREAS

	Surface mining	Underground mining	Combined
Coal mining in Appalachia only	43.25 ( $p < 0.001$ )	42.08 ( $p < 0.001$ )	41.39 ( $p < 0.0004$ )
Coal mining outside of Appalachia	-2.71 ( $p < 0.84$ )	15.84 ( $p < 0.38$ )	5.14 ( $p < 0.65$ )
Coal mining nationwide	17.21 ( $p < 0.06$ )	31.56 ( $p < 0.002$ )	21.50 ( $p < 0.006$ )

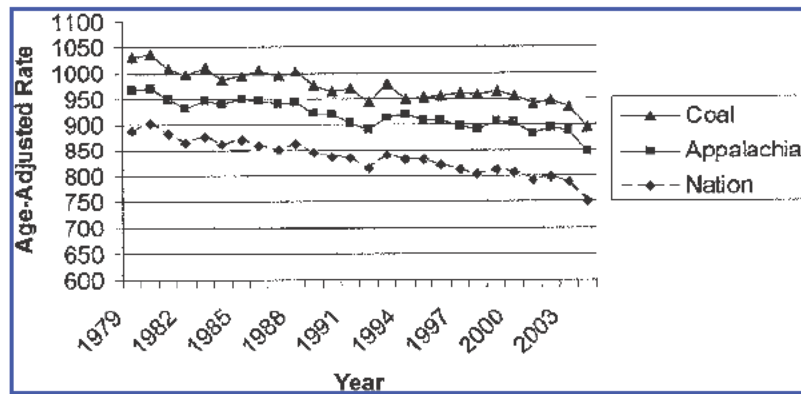


FIG. 2. Age-adjusted mortality per 100,000, 1979–2004, by county type (Appalachian coal mining, other Appalachian, or rest of nation). Model  $F = 1422.7$  ( $df = 3, 81,622$ ,  $p < .0001$ ).

ing impurities through a chemical washing process. These preparation activities take place near the mining sites for both underground and surface operations. In addition to impurities removed by washing, chemicals used in the washing process may themselves be toxic.<sup>39</sup> The contaminated water, called slurry, is held in impoundment ponds or injected underground, where it poses risk of leaking into freshwater sources.<sup>40</sup> There are 111 impoundment ponds in West Virginia alone, holding more than 140 billion gallons of coal slurry.<sup>41</sup>

The environmental health impacts of the coal mining industry may operate through water and air transport routes. Shiber<sup>42</sup> reports elevated arsenic levels in drinking water sources in coal mining areas of central Appalachia. Other studies of water quality near coal mining in Appalachia have been conducted<sup>43–45</sup> showing that surface water and private well water are contaminated in ways consistent with coal slurry. Studies of local air quality in Appalachian coal mining communities have not been done, and constitute an important next step in this line of research. However, particle constituents in ambient air from coal mining or processing may occur at fine ( $PM_{2.5}$ ) or coarse ( $PM_{10}$ ) modes.<sup>46</sup> Coal particulates may also interact with diesel particulate matter; diesel engines are commonly used at mining and processing sites. Research has linked urban air pollution to premature mortality<sup>47,48</sup> possibly from the exacerbation of acute or pre-existing illness. It may be the case that pollution from coal mining and processing activities has a similar effect.

Ironically, removal of coal impurities and crushing of coal into smaller pieces, although intended as an environmental protection step and to increase the efficiency of burning, result in impurities being left behind in the vicinity of coal mining communities. The coal cleaning process is described as “removing” impurities prior to burning,<sup>49</sup> but it would be more precise to say that these impurities are merely “relocated.”

Limitations of the study include the ecological design, the imprecision of covariates, and the limited availability of coal mining data. Individual causes of mortality and their relationship to mining or other variables may be suggested but cannot be proven with a county-level analy-

sis. Smoking was imprecisely estimated, and other behavioral contributions to mortality such as diet or alcohol consumption were not included, although these behavioral variables are known to correlate with other measures that were included such as education and poverty. Coal mining was measured only for the years 1999–2004; for the test of hypothesis 3 the reasonable but unproven assumption was made that this estimate reflected earlier mining activity. Mining effects in Appalachia were found for both underground and surface techniques (although the coefficient was slightly higher for surface mining); more specific forms, such as mountaintop removal versus other forms of surface mining could not be examined. Furthermore, key aspects of coal processing, including chemical washing and transportation, could not be linked to mortality data because of the lack of data specificity. Given that both surface and underground mining were related to mortality, it is important that future research examine population health effects from mining industry activity that are common to both methods, including relating operations of local coal processing facilities to measures of air and water quality and to health outcomes.

Ultimately, regardless of whether the persistently elevated mortality rates found in Appalachian coal mining areas result from environmental, social, economic, or behavioral causes, it is clear that serious health disparities persist in these areas and must be addressed. The underlying causes of health disparities are founded in economic, educational, and environmental injustices.<sup>50–52</sup> To reduce and eliminate disparities requires that these root causes be attacked. For coal mining areas of Appalachia, this means that alternative and sustainable economies be developed, as a continued reliance on a coal-based economy will only perpetuate disparities. Results also highlight the need for improvements in environmental equity: people who live in these areas are subject to environmental degradation and exposure to pollutants in exchange for development of a relatively cheap energy source for many of the rest of us to enjoy.

The argument is often made that coal mining is an important economic contributor to the areas of Appalachia

where mining takes place,<sup>53</sup> and therefore that mining should be protected and encouraged. The first part of this argument is correct, but the second part is fallacious. Coal mining perpetuates poverty, environmental degradation, economic underdevelopment, and premature death. That it is an important part of a perpetually weak economy is no endorsement for its continuation. Coal mining remains an important part of these economies because underdeveloped infrastructure, blasted landscapes, poorly educated workforces, environmental health hazards, and chronically unhealthy populations perpetuate themselves over time and present strong discouragement to new business and population immigration.

Construction of more diverse, alternative economies should be undertaken. Such efforts could include sustainable timber or agriculture, development of marketable alternative energy such as wind power, investments in education and technology, and entrepreneurial ventures. Microcredit programs may be attempted as has been done successfully in parts of the developing world.<sup>54</sup> Business incubators to support small start-up ventures have been implemented in other parts of Appalachia<sup>55</sup> and may be extended to the coalfields. Ecosystem restoration to reclaim lands destroyed by mining may create jobs and business opportunities.<sup>56</sup> Regulatory and allocative policies may be implemented and enforced to require coal companies to reduce environmental impacts and to return greater portions of coal revenue to the places where the coal is mined, rather than to corporate offices located outside the region.

Finally, we should recognize that coal is mined primarily because there is a national and international market for it, whether or not it benefits the local population. Global initiatives are underway to increase use of alternative energy sources, and to re-calibrate the price of coal through consideration of environmental costs via carbon taxes or cap-and-trade programs. Such initiatives are critical to mitigate effects of climate change, and if implemented could dramatically reduce reliance on this polluting energy source.<sup>57</sup> Reductions in the external demand for coal will provide a crisis and an opportunity for the people of the Appalachian coalfields to redefine themselves and create healthier environments in a post-carbon world.

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## Executive Summary

Catherine Salipante Zaidel, MEM  
Jonathan Borak, MD, FACP, FACOEM

May 6, 2010

We reviewed 8 peer-reviewed journal articles, authored by Dr. Michael Hendryx, on the health of coal mining communities in Appalachia. We found a number of factual discrepancies and methodological flaws in those articles. Those discrepancies and flaws fall into three primary categories of concern: (1) inconsistencies in the definitions and numbers of “high” and “low” coal-producing counties in Appalachia; (2) failure to consider some important covariates and limited or missing data for others; and, (3) inability of the study design and findings to support some of the authors’ conclusions.

(1) The total number of counties considered and the ways that they were divided into high vs. low coal-producing counties varied across studies. Two studies counted 413 total Appalachia counties, whereas two other studies counted 417 total counties. Three different criteria were used in different studies to characterize “high” vs. “low” coal-producing counties. No explanation or justification for these varying criteria was provided.

(2) Key factors expected to directly influence study outcomes, obesity, diabetes and alcohol consumption, were omitted from the analyses. The significance of such deficiencies is emphasized by Hendryx’ published observation that diabetes causes greater morbidity and mortality in Appalachia than in the rest of the country. The Hendryx studies attempt to control for smoking, but there is a lack of county-specific smoking data for some of the Appalachian states. In those cases, his analyses use data for the state or for country aggregates, which almost certainly misclassify risks. This is of particular concern because Hendryx has reported that smoking rates are higher in Appalachian coal mining counties vs. non-coal mining counties.

(3) The Hendryx studies employ an ecological study design, i.e., “exposure” is determined by group location, not by individual exposures, but the study conclusions presume that group differences are attributable to individual exposures, e.g., to the effects of coal mining. One study found excess mortality rates in Appalachian coal mining communities, but not in coal mining communities in other areas of the country. Likewise, he attributes increased mortality to proximity to coal mining, but not to being a coal miner.

Our review illuminates a number of methodological concerns in the Hendryx research, but is not able to determine the magnitude of the resulting study bias. Further analysis, including data excluded in the Hendryx studies, would be necessary to estimate the actual magnitude and direction of such bias and to determine whether his findings are replicable.

Table 1 lists the Hendryx studies reviewed and the acronym by which each is described in the following text and discussion:

TABLE 1. Reviewed Hendryx Studies with Associated Acronyms	
Acronym	Study
EH	Hitt NP, Hendryx M. Ecological integrity of streams related to human cancer mortality rates. <i>EcoHealth</i> . <b>2010</b> .
PHR	Hendryx M, Ahern MH. Mortality in Appalachian coal mining regions: the value of statistical life lost. <i>Public Health Reports</i> . <b>2009</b> ; 124: 541-550.
JRH	Pollard C, et al. Electronic patient registries improve diabetes care and clinical outcomes in rural community health centers. <i>The Journal of Rural Health</i> . <b>2009</b> ; 25(1): 77-84.
EJ	Hendryx M. Mortality rates in Appalachia coal mining counties: 24 years behind the nation. <i>Environmental Justice</i> . <b>2008</b> ; 1(1): 5-11.
IA	Hendryx M. Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. <i>Int Arch Occup Environ Health</i> . <b>2008</b> ; 82: 243-249.
LC	Hendryx M, O'Donnell K, Horn K. Lung cancer mortality is elevated in coal-mining areas of Appalachia. <i>Lung Cancer</i> . <b>2008</b> ; 62: 1-7.
AJPH	Hendryx M, Ahern MH. Relations between health indicators and residential proximity to coal mining in West Virginia. <i>American Journal of Public Health</i> . <b>2008</b> ; 98(4): 669-671.
JTEH	Hendryx M, Ahern MH, Nurkiewicz TR. Hospitalization patterns associated with Appalachian coal mining. <i>J of Toxicology and Environ Health</i> . <b>2007</b> ; 70: 2064-2070.

1. Number of Appalachia Counties: The number of counties in Appalachia differs among Hendryx's studies and the Appalachian Regional Commission.
  - In the *PHR* and *LC* studies, Hendryx states that there are **413** counties in Appalachia.
  - In the *EJ* and *IA* studies he states that there are **417** counties as defined by the Appalachian Regional Commission.
  - Currently, however, the Appalachian Regional Commission states that **420** counties are part of Appalachia.
2. Definition of "High" v. "Low" Coal Producing Counties: The definition of "high" v. "low" coal producing counties differs between Hendryx's studies.
  - Coal production is a categorical variable in Hendryx's studies. However, the delineation between "high" and "low" coal production is different in each study. He does not explain why he uses different definitions.
  - The comparison counties and the total number of counties are different in each study. The US Census Bureau lists 3,140 total counties or county-equivalent administrative units in the United States.
  - The *EJ* study used two different methods to estimate exposure to coal mining. The first method divided counties based on the sum of coal production during 1999-2004. The

cutoff was 4 million tons. The second method divided counties based on coal production per capita, found by dividing county tons mined by the county population. The cutoff was 200 tons per person. This study only reported the number of counties in the “high” and “low” coal production categories as divided by 4 million tons. It does not report how many counties are in each of the other categories.

- The *EJ* study excluded from the analysis 104 non-Appalachian counties where coal mining took place but no explanation is given for why they were excluded (p. 6).
- The *AJPH* study was conducted at the individual level, as opposed to the county-level, using data from a telephone survey of 16,493 adults. This study also uses 4 million tons as the cutoff between “high” and “low” coal producing counties.
- The *JTEH* study was conducted at the individual level, as opposed to the county-level, using data from 2001 adult hospitalizations ( $n = 93,952$ ) for West Virginia, Kentucky, and Pennsylvania. “The coal production variable was transformed by taking the square root of tons of coal measured in thousands. The coal production variable was linked to the hospital records at the county-level” (p. 2066). No division of “high” v “low” counties was used.
- The geographic area of counties varies. Coal production values were adjusted to area only in the *EH* study.
- Table 2 below demonstrates these differences:

**TABLE 2. Definition and Numbers of “High” v “Low” Coal Producing Counties in Hendryx’s Studies**

Study	High/Low Cutoff	Data Years	Number of Appalachian Counties in “High” Group	Number of Appalachian Counties in “Low” Group	Total Appalachian Coal Producing Counties	Comparison Counties 1	Comparison Counties 2	Total Counties
<i>IA</i>	4 million tons	2000-2004	66	63	129	97 “Non-Appalachian mining”	2,914 “No Mining”	3,140
<i>EJ Method 1</i>	4 million tons	1999-2004	67	65	132	Not reported “Non-mining Appalachia”	Not reported “	3,141
<i>EJ Method 2</i>	200 tons per person	1999-2004	Not reported	Not reported	-----	Not reported “Non-mining Appalachia”	Not reported “Non-mining Rest of Nation”	3,141
<i>LC</i>	3 million tons	2000-2004	66	Not reported	-----	347 “Other Appalachian”	2,615 “Rest of Nation”	3,028
<i>PHR</i>	median	1994-2005	70	69	139	274 “Non-mining Appalachia”	2,728 “Rest of Nation”	3,141

Table 3 presents the number of counties in the “high” and “low” coal production counties using the raw data that we gathered for the years 2000-2004:

<b>TABLE 3. Number of Counties in “High” and “Low” Coal Producing Counties Using the Data We Collected</b>		
	<b>Number of Counties in “High” Group</b>	<b>Number of Counties in “Low” Group</b>
<b>4 million tons</b>	66	63
<b>3 million tons</b>	67	62
<b>Median</b>	65	64

3. Obesity, Diabetes and Alcohol Consumption: Hendryx excluded potentially important covariates. Because both obesity and diabetes are such important risk factors for mortality, we were surprised that neither had been explicitly included in the analyses. Such problems are likely to impact most of the Appalachian coal mining counties.
  - The CDC has said that Appalachia has one of the highest rates of obesity and diabetes in the country.
  - The *JRH* study noted that the prevalence of diabetes in West Virginia was nearly twice the national average.
  - The *JRH* study also noted that: “West Virginia’s diabetes problem is impacted through its rural geography, which limits access to health care” (p. 77).
  - The *EJ* study stated that “other behavioral contributions to mortality such as diet or alcohol consumption were not included, although these behavioral variables are known to correlate with other measures that were included such as education and poverty” (p. 9).
4. Missing or Limited Data on Important Covariates:
  - The *PHR* and *EJ* studies perform the same basic analysis of mortality rates compared to the level of coal production. In the *EJ* study, Hendryx excluded 61 counties from the regression analysis due to missing data on covariates (p. 5). However, the missing data were not mentioned and the specific counties were not excluded in the *PHR* study.
  - The *PHR* and *EJ* studies use coal production data from 1994-2005 as a proxy for coal production in counties during the entire analysis period (1979-2005). This assumes that county coal production rates have remained relatively constant during this entire period.
  - Hendryx admits in his *EJ* study that the data are limited: “coal production figures for years prior to 1999 are not readily available for all counties.” (p. 6).
  - Data for many covariates were not available for the same year: median household income (mean from 2000-2003), poverty rate (mean from 2000-2002), high school education (2000), unemployment rates (2000) coal production data (1997-2005).
  - In all but one of the studies, only data on coal production (not the locations of coal processing facilities, coal slurry impoundments or permitted slurry injection sites) were considered; the *EH* study considered all three.

5. **Imprecise Estimate of Smoking Rates:** Since smoking rates are often higher in coal producing counties, imprecise measurements for smoking could lead to an inability to adequately control for smoking-related health effects and mortality in the regression analyses.
  - Hendryx himself explains in the *EJ* study that smoking rates were “imprecisely estimated” (p. 9).
  - The methodology for gathering smoking data that was used the *PHR*, *IA*, *LC*, *EJ*, *EH* studies are as follows: Smoking rates were obtained from the CDC’s Behavioral Risk Factor Surveillance System (BRFSS). Data are only available at the county-level for some metropolitan areas. Additional BRFSS data are available from each state’s public health website at the level of the county or groups of counties. State averages are used when county-level data were not available.
  - The counties grouped together for smoking rate data often have varying rates of coal production. The tables in Appendix A demonstrate this for West Virginia and Kentucky data.
  - The use of grouped county data is especially relevant because Hendryx’s studies reported that smoking rates were significantly increased in counties with high levels of coal production. For example, in the *IA* study, Table 1 (see Appendix B) indicates apparently significant differences between counties with >4 million tons vs. non-mining counties (29.2 vs. 23). In the *LC* study, Table 1 (see Appendix C) indicates a significantly higher smoking rate in the Appalachian counties with “High coal mining” vs. “Other Appalachian” counties and Table 2 (see Appendix D) indicates a highly significant relationship between smoking rate and coal production.
  - The available smoking data are often not directly comparable. In some cases, data are only available for different years (e.g., Alabama currently makes available data for 2007, while Kentucky presents only 2000-2003 data).
  - Some states provide data for two smoking categories (smoking: yes/no) while others present data for 4 categories (smoking: current everyday; current/occasional; former smoker; never smoker).
6. **Mortality Cause:**
  - In the *EJ* study, Hendryx excluded deaths caused by external factors, including homicide, suicide, motor vehicle accidents and other accidents. In the *PHR* study, these deaths were included in the analysis. He states only that “we examined total mortality rates for all causes, and included all ages” (p. 542).
7. **Ecological Study Design:** The conclusions that he makes in the discussion section of his paper are not necessarily supported by the study.
  - Hendryx admits the limitations of his methodology in the *EJ* study: “Limitations of the study include the ecological design, the imprecision of covariates, and the limited availability of coal mining data. Individual causes of mortality and their relationship to mining or other variables may be suggested but cannot be proven with a county-level analysis.” (p. 9)
  - He can conclude from the *PHR* and *EH* studies that higher mortality rates were found in areas with higher levels of coal mining, but he cannot conclude that environmental pollution from coal mining is what caused these deaths.

- He also cannot conclude from his studies that coal mining is the cause of the poverty and poor education rates in the coal mining areas of Appalachia.
- By their nature, the Hendryx studies are ecological, i.e., the study design is unable to assess individual exposure to the potential environmental contaminants from coal mining, but the studies presume that differences between groups are due to coal mining.

## 8. Employment data:

- The *PHR* study states: “Comparing the economic report [Thompson] with EIA figures indicated an 11% decrease in employment in Appalachian coal mining from 1997 to 2005” (p. 546). The numbers of counties were not the same in those two reports (EIA: 126 Appalachian coal producing counties for 2004; Thompson: 118 coal producing counties for 1997). Considering the differences between the two databases, it is possible that the employment difference was an artifact of the different numbers of counties in the two reports.
- Review of the employment data from the EIA files indicates that the number of Appalachian coal miners decreased from 1998 to 1999, but that employment has increased since then. It is possible that there was a one-time drop in employment and the employment rates will continue to rise.

## 9. Attributing Excess Deaths to Coal Mining:

- In both the *EJ* and *PHR* studies Hendryx, found that higher rates of mortality existed for Appalachian coal mining areas but not coal mining areas elsewhere: “Coal mining effects were significant for Appalachia and the combined analysis for both underground and surface mining, but not for coal-mining limited to areas outside of Appalachia (the analysis of non-Appalachian coal mining effects deleted Appalachian coal mining counties.)” (*EJ*, p. 7-8) See figure 1 below for a summary of Hendryx results.
- However, he concluded the following: “That effects were found for Appalachia coal mining areas but not coal mining areas elsewhere may reflect the unique relationship of mining activity to topography and population centers characteristic of Appalachia” (p. 8).
- These results also suggest that coal mining is not the reason for the excess deaths.

FIGURE 1.

TABLE 3. (≥4 Mi AND E
Coal mining i Appalachia Coal mining c of Appalac Coal mining nationwide

Source: *EJ*

### 10. Data Redundancy:

- Population Sizes & Rural-Urban Variable: Areas with coal mining have much smaller population sizes— it is not evident that this is fully controlled for by the rural-urban continuum code. Are data as reliable in rural areas compared to urban areas?
- Median Household Income, Poverty Rates & Unemployment Rates: All are measures of wealth; should they be counted 3 times?
- Spatial Autocorrelation: The *EH* study indicates a high degree of spatial data clustering. How does this impact the analyses?

APPENDIX A. Counties in Kentucky and West Virginia that were grouped together by smoking rates but have wide ranging levels of coal production.

<b>KENTUCKY: BIG SANDY DEVELOPMENT DISTRICT</b>								
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>		
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2004</b>	<b>2003</b>	<b>2002</b>
<b>Floyd</b>	2,990	3,193	2,870	3,365	2,678	31.1	37.0	37.6
<b>Johnson</b>	308	475	513	543	491			
<b>Magofin</b>	748	67	20	0	0			
<b>Martin</b>	6,229	8,900	9,508	9,822	11,138			
<b>Pike</b>	28,113	27,547	30,001	34,049	34,009			

<b>KENTUCKY: CUMBERLAND VALLEY DEVELOPMENT DISTRICT</b>								
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>		
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2004</b>	<b>2003</b>	<b>2002</b>
<b>Bell</b>	1,372	2,081	2,519	2,582	0	29.9	38.9	39.5
<b>Clay</b>	56	318	103	67	9			
<b>Harlan</b>	11,928	10,548	10,784	12,410	10,125			
<b>Jackson</b>	47	31	23	0	0			
<b>Knox</b>	758	519	417	425	389			
<b>Laurel</b>	81	53	34	28	29			
<b>Rockcastle</b>	0	0	0	0	0			
<b>Whitley</b>	309	196	204	118	176			

<b>KENTUCKY: KENTUCKY RIVER DEVELOPMENT DISTRICT</b>								
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>		
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2004</b>	<b>2003</b>	<b>2002</b>
<b>Breathitt</b>	925	1,751	1,435	1,303	1,026	31.8	35.5	40.6
<b>Knott</b>	11,091	10,201	10,784	12,894	12,633			
<b>Lee</b>	18	18	49	3	0			
<b>Leslie</b>	4,462	5,220	6,099	6,460	7,286			
<b>Letcher</b>	7,506	6,449	8,951	10,649	9,479			
<b>Owsley</b>	74	105	48	37	22			
<b>Perry</b>	12,081	12,045	13,522	13,672	12,301			
<b>Wolfe</b>	0	0	0	0	0			

Kentucky Smoking Data Source: (Kentucky Cabinet for Health and Family Services, BRFSS)  
<http://chfs.ky.gov/NR/rdonlyres/8A61BC13-336E-4DFA-A540-4FD8DBE3ACD4/0/smoker2a.pdf>

<b>WEST VIRGINIA: Boone/Lincoln</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Boone</b>	31,270	30,308	31,932	31,677	31,922	30.2
<b>Lincoln</b>	777	235	327	1766	734	

<b>WEST VIRGINIA: Greenbrier/Summers/Monroe</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Greenbrier</b>	606	576	757	779	563	21.7
<b>Summers</b>	0	0	0	0	0	
<b>Monroe</b>	0	0	0	0	0	

<b>WEST VIRGINIA: Braxton/Nicholas/Webster</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Braxton</b>	0	0	0	0	0	26.1
<b>Nicholas</b>	4,875	5,298	4,969	5,610	4,826	
<b>Webster</b>	4,706	4,915	5,661	5,832	5,595	

<b>WEST VIRGINIA: Calhoun/Clay/Gilmer/Roane</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Calhoun</b>	0	0	0	0	0	34.5
<b>Clay</b>	4,158	3,879	4,215	4,570	5,128	
<b>Gilmer</b>	0	0	0	0	0	
<b>Roane</b>	0	0	0	0	0	

<b>WEST VIRGINIA: Barbour/Taylor</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Barbour</b>	968	989	916	568	659	21.6
<b>Taylor</b>	0	0	0	0	0	

<b>WEST VIRGINIA: Preston/Tucker</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Preston</b>	1,858	2,406	2,464	2,465	1,232	25.7

<b>Tucker</b>	0	67	131	277	202	
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<b>WEST VIRGINIA: Grant/Mineral</b>						
<b>COUNTIES</b>	<b>COAL (Thousand Short Tons)</b>					<b>SMOKING (% Current)</b>
	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>	<b>2000</b>	<b>2001-2005</b>
<b>Grant</b>	1,181	1,364	1,437	774	652	27.7
<b>Mineral</b>	88	70	69	90	45	

West Virginia Smoking Data Source: (West Virginia Department of Health and Human Resources, BRFSS) [http://www.wvdhhr.org/bph/hsc/pubs/BRFSS/2004\\_2005/default.htm](http://www.wvdhhr.org/bph/hsc/pubs/BRFSS/2004_2005/default.htm)

APPENDIX B. Table from the *IA* study showing a statistically significant difference in smoking rate between counties that produce coal and those that do not.

<sup>c</sup> Includes chrc  
<sup>d</sup> Includes pnei  
<sup>e</sup> Includes chrc  
renal failure (N  
<sup>f</sup> Includes acut

Source: *IA*

APPENDIX C. Table from the *LC* study demonstrating significantly higher smoking rates for “Heavy Appalachian coal mining” areas versus “Other Appalachian” areas.

Percent with Mean physical	Percent with Mean physical	Percent with Mean physical	Percent with Mean physical
<sup>a</sup> Post hoc test	<sup>b</sup> Coal mining	<sup>c</sup> Coal-mining	<sup>d</sup> Post hoc test

Source: *LC*

APPENDIX D. Table from the *LC* study demonstrating a significant association between coal mining and smoking rate.

Micropolitan  
South  
Primary care  
per 1000

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<sup>a</sup>  $F = 122.6$  ( $p < .001$ )  
<sup>b</sup>  $F = 122.8$  ( $p < .001$ )

Source: *LC*

# Mortality in Appalachian Coal Mining Regions: The Value of Statistical Life Lost

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MELISSA M. AHERN, PhD<sup>b</sup>

## SYNOPSIS

**Objectives.** We examined elevated mortality rates in Appalachian coal mining areas for 1979–2005, and estimated the corresponding value of statistical life (VSL) lost relative to the economic benefits of the coal mining industry.

**Methods.** We compared age-adjusted mortality rates and socioeconomic conditions across four county groups: Appalachia with high levels of coal mining, Appalachia with lower mining levels, Appalachia without coal mining, and other counties in the nation. We converted mortality estimates to VSL estimates and compared the results with the economic contribution of coal mining. We also conducted a discount analysis to estimate current benefits relative to future mortality costs.

**Results.** The heaviest coal mining areas of Appalachia had the poorest socioeconomic conditions. Before adjusting for covariates, the number of excess annual age-adjusted deaths in coal mining areas ranged from 3,975 to 10,923, depending on years studied and comparison group. Corresponding VSL estimates ranged from \$18.563 billion to \$84.544 billion, with a point estimate of \$50.010 billion, greater than the \$8.088 billion economic contribution of coal mining. After adjusting for covariates, the number of excess annual deaths in mining areas ranged from 1,736 to 2,889, and VSL costs continued to exceed the benefits of mining. Discounting VSL costs into the future resulted in excess costs relative to benefits in seven of eight conditions, with a point estimate of \$41.846 billion.

**Conclusions.** Research priorities to reduce Appalachian health disparities should focus on reducing disparities in the coalfields. The human cost of the Appalachian coal mining economy outweighs its economic benefits.

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The Appalachian region of the United States has long been associated with severe socioeconomic disadvantages.<sup>1-3</sup> These disadvantages translate to poor public health outcomes including elevated morbidity and mortality rates for a variety of serious, chronic conditions, such as diabetes, heart disease, and some forms of cancer.<sup>4-6</sup> The problems are so severe and persistent that the National Institutes of Health (NIH) has included Appalachia among its target priorities for the reduction and elimination of health disparities.<sup>7</sup>

Coal mining constitutes a major economic activity in some portions of Appalachia.<sup>8</sup> As with Appalachia in general, the region's coal mining areas have been linked to socioeconomic disadvantages.<sup>1,9,10</sup> Appalachian areas where economic disadvantage has been most persistent over time are those characterized by low economic diversification, low employment in professional services, and low educational attainment rates.<sup>2</sup> These features are characteristic of tobacco- and coal-dependent economies.<sup>11</sup> Rural economies dependent on sole-source resource extraction are vulnerable to employment declines and market fluctuations.<sup>12</sup>

Based on social disparities models<sup>13,14</sup> that link poor health to socioeconomic disadvantage, one would expect to see elevated morbidity and mortality in mining areas resulting from the socioeconomic disadvantages that are prevalent in these areas. Recent empirical studies have indeed confirmed that health disparities exist in coal mining regions of Appalachia compared with other areas of the region or the nation, including elevated mortality rates for total causes, lung cancer, and some chronic illnesses.<sup>15-19</sup> These studies showed that mortality is related to higher poverty, lower education levels, and smoking behavior, and also suggested that environmental pollution from the mining industry is a contributing factor.

The reliance on coal mining in some areas of Appalachia constitutes a *de facto* economic policy: coal is mined because it is present and because there is a market for it. However, other economic policies could be developed if reliance on this resource was not in the best interest of the local population. This study evaluated the costs and benefits associated with the Appalachian coal mining economy. We first estimated the number of excess annualized deaths in coal mining areas for the period 1979 through 2005 and converted those estimates to monetary costs using value of statistical life (VSL) figures from prior research.<sup>20-23</sup> Then, we compared VSL costs with an estimate of the economic benefits of coal mining to test whether the economic benefits of coal mining in Appalachia exceeded the estimated VSL costs.

## METHODS

### Design

This study retrospectively investigated national mortality rates for the years 1979–2005. The level of analysis was the county ( $n=3,141$ ). We compared four groups: counties in Appalachia with levels of coal mining above the median, Appalachian counties with levels of mining below the median, non-mining counties in Appalachia, and other counties in the nation. The study, an analysis of anonymous, secondary data sources, met university Internal Review Board standards for an exception from human subjects review.

### Data

We obtained publicly available mortality data for 1979 through 2005 from the Centers for Disease Control and Prevention (CDC). These data measure county-level mortality rates per 100,000, age-adjusted using the 2000 U.S. standard population.<sup>24</sup> We examined total mortality rates for all causes, and included all ages.

We obtained coal employment and production data from the Energy Information Administration (EIA),<sup>25</sup> measured as tons of coal mined in every county every year for the years 1994–2005. The EIA does not provide county-specific data prior to 1994. For the current study, we defined coal mining areas as counties with any amount of coal mining during those years. For some analyses, we divided coal mining counties into those with higher or lower amounts of mining based on a median split of production figures. In most cases, counties that mined coal in one year did so in most or all years, due simply to the presence of economically minable coal in the county. However, we placed seven counties that had small amounts of mining prior to 1997 and no mining after that time with the non-mining counties to focus the analysis on areas with more contemporary mining, as some analyses were limited to the period 1997–2005. There is also considerable historical evidence that Appalachian counties characterized by coal mining during recent years were also coal mining areas in previous years and decades,<sup>1,26-28</sup> so we used mining during the 1994–2005 period as a proxy for mining during the entire study period.

We obtained data on county socioeconomic characteristics from the 2005 Area Resource File<sup>29</sup> and the Appalachian Regional Commission.<sup>30</sup> Area Resource File data were in turn drawn from U.S. Census data and were based either on the 2000 Census or on multi-year estimates when available. We used these data to compare coal mining areas with other areas using the following categories: median household income (the mean for 2000–2002), poverty rates (the mean for

2000–2002), 2000 high school and college education rates, and 2000 unemployment rates. We obtained smoking rates from Behavioral Risk Factor Surveillance System survey results from CDC,<sup>31</sup> supplemented with additional data found by reviewing all 50 states' public health websites.

We calculated estimates for the VSL based on prior VSL research conducted by U.S. regulatory agencies.<sup>20–23</sup> VSL estimates were based on trade-offs between risks (e.g., probability of mortality from breathing polluted air) and money (e.g., the cost of reducing that risk), and provided a reference point to assess the benefits of risk-reduction efforts. VSL estimates are used by government agencies such as the Environmental Protection Agency (EPA), Food and Drug Administration, and others to conduct cost-benefit analyses of pollution control policies or other public benefit programs. The two estimates that we used in the current study were (1) the calculated mean VSL of \$3.8 million per life across 18 U.S. regulatory agency studies reported by Viscusi and Aldy and (2) the EPA estimate of \$6.3 million to represent environmental policies pertinent to the current investigation.<sup>23</sup> We measured both of these estimates in 2000 dollars, and converted them to 2005 dollars as described further in this article.

We estimated the economic benefit of coal mining from a 2001 report of the direct, indirect, and induced economic contributions of the coal mining industry in Appalachia.<sup>32</sup> This report was based on earnings and coal production in 1997. Direct contributions include earnings from coal company employees, including laborers and proprietors; indirect and induced contributions include earnings by other sectors based on multiplier effects of the industry (e.g., supplies purchased locally by coal companies and coal company employee expenditures on other goods and services). We made adjustments to reflect the 4.35% mean annual increase in the Consumer Price Index between 1997 and 2005, and the 11% decline in Appalachian coal mining employment during the same time period.

In addition to these economic benefits, some states imposed coal severance taxes that provided additional economic input to these states.<sup>32</sup> West Virginia, for example, imposed a 5.0% coal severance tax on the sales price per ton, the tax in Kentucky was 4.5%, and in Tennessee it was \$0.20 per ton. In contrast, states also provided various tax incentives related to the coal industry: Maryland, Ohio, and Virginia provided a corporate tax credit of \$3.00 per ton for burning indigenous coal, and the credit in Kentucky was \$2.00 per ton. Alabama and Virginia provided tax incentives to coal companies to increase production. The final estimate of economic contributions included

the adjusted sum of the indirect, direct, and induced contributions, plus the net contributions of the severance tax, minus the tax credits.

### Analysis

We analyzed the data using SAS<sup>®</sup> 9.1.3.<sup>33</sup> We tested mean group differences using least squares linear models. Where indicated, post-hoc Type I error corrections used the Ryan-Einot-Gabriel-Welsch Multiple Range Test. We conducted ordinary least squares multiple regression models with age-adjusted mortality as the dependent variable and mining, socioeconomic, and demographic indicators as independent variables to identify mining effects independently of other effects. We converted unadjusted and covariate-adjusted annual mortality rates to excess number of deaths in mining areas using census population data, and then multiplied these figures by the VSL estimates to find a range of the economic cost of coal mining, which we then compared with the estimated economic benefit.

There is evidence that some health impacts from economic and environmental disadvantage occur in the short term,<sup>34–37</sup> but that other effects are delayed.<sup>38,39</sup> Discounting future costs is one way to account for delayed effects; however, discounting has proponents<sup>23,40,41</sup> and detractors,<sup>36</sup> and there are unknowns in the choice of time periods, discount rates, and uncertainties of how people value future health benefits.<sup>42</sup> Nevertheless, we conducted a discount analysis based on previous research that used a 10-year, 3% discount rate to study cancer mortality;<sup>38</sup> we selected a 2% discount to recognize that not all health impacts would be delayed. We compared the 2005 benefits of coal mining with future discounted VSL costs using eight scenarios, including lower or higher VSL, unadjusted or adjusted covariate analysis, and Appalachia or the nation as the comparison group.

## RESULTS

### Socioeconomic characteristics

Table 1 presents socioeconomic indicators and age-adjusted mortality rates for four groups of counties: Appalachian counties with levels of mining above the median, Appalachian counties with levels of mining below the median, Appalachian counties with no mining, and the rest of the nation. Significant post-hoc differences between groups were corrected for Type I error at  $p < 0.05$ . Coal mining areas fared significantly worse on all indicators compared with non-mining areas of Appalachia and/or the nation. These conditions worsened as levels of mining increased: the highest levels of unemployment and lowest incomes

**Table 1. Socioeconomic measures and annual age-adjusted mortality from 1979 to 2005 for four groups**

Socioeconomic measure	Appalachian counties with coal mining above the median <sup>a</sup>	Appalachian counties with coal mining below the median <sup>a</sup>	Non-mining Appalachian counties	Rest of nation	P-value
Number	70	69	274	2,728	
Median household income <sup>b</sup>	\$28,287	\$30,614	\$33,078	\$36,622	0.0001
Poverty rate <sup>c</sup>	18.0	16.5	14.5	13.3	0.0001
Percent of adults with high school education <sup>d</sup>	69.8	71.3	71.5	78.3	0.0001
Percent of adults with college education <sup>b</sup>	11.2	12.6	13.8	17.0	0.0001
Unemployment rate <sup>e</sup>	7.0	6.0	5.0	4.7	0.0001
Age-adjusted mortality per 100,000 <sup>f</sup>	1,049.0	1,007.3	985.6	932.7	0.0001

<sup>a</sup>The median split refers to mining counties with greater than, or less than, the median tons of coal mined during the combined years 1994–2005; this median figure is 7,785,000 tons.

<sup>b</sup>Higher coal mining was significantly different from all groups; lower coal mining was significantly different from the nation.

<sup>c</sup>Both coal mining locations were significantly different from others.

<sup>d</sup>All three Appalachian groups were significantly different from the nation.

<sup>e</sup>Higher coal mining was significantly different from all groups, and lower coal mining was significantly different from all groups.

<sup>f</sup>Higher coal mining was significantly different from all groups, and both other Appalachian groups were significantly different from the nation.

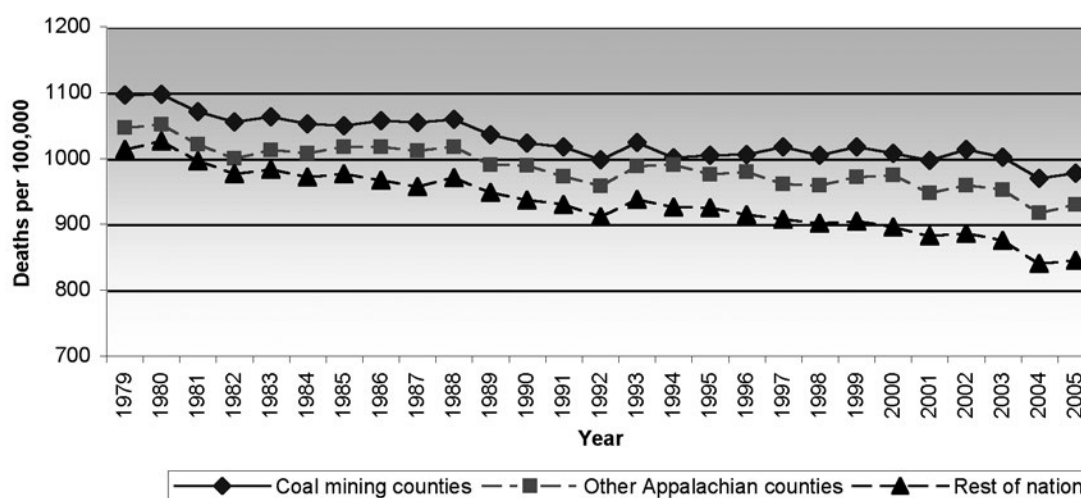
were located in the areas where the heaviest mining activity took place. For two indicators, poverty and unemployment, the disparity was unique to mining areas; that is, an Appalachian disparity compared with the nation did not exist outside of coal mining areas. Age-adjusted mortality was highest in areas of heaviest coal mining.

Reductions in employment in the industry over time indicated the poor economic conditions of mining areas. The number of coal miners in Appalachia declined from 122,102 to 53,509 between 1985 and 2005. This decline corresponded to increases in mechanized mining practices and the growth of surface min-

ing, which requires fewer employees than underground mining per ton mined.<sup>43</sup>

#### Age-adjusted mortality rates

The Figure presents the age-adjusted total mortality rates for three groups of counties for 1979 through 2005. We combined higher and lower levels of mining for this analysis. Significant main effects were present for time ( $F=869.8$ ,  $p<0.0001$ ) and county group ( $F=23.6$ ,  $p<0.0001$ ), and for the interaction of time and group ( $F=24.8$ ,  $p<0.0001$ ). (Mortality rates are sometimes studied using log normal distributions; we repeated this test on the log values of mortality rates

**Figure. Total age-adjusted mortality per 100,000 for the years 1979–2005, by county group**

and still found significant main effect and interaction terms at the same levels of *p*-values.) Historic trends showed declining mortality rates for all groups, but coal mining areas had the highest rates for every year. Non-mining areas of Appalachia had intermediate rates. The time  $\times$  group interaction indicated that the gap between non-Appalachian counties and both other county groups increased; this increasing gap became most evident in 1997 and subsequent years as shown in the Figure. As illustrated, the mean gap between coal mining areas and the nation in the first five years (1979–1983) was 77.6 excess deaths per 100,000 and increased to 126.0 excess deaths per 100,000 during the last five years (2001–2005). The trend between coal mining areas and other areas of Appalachia was more complex, as the gap between these groups of counties declined prior to 1997, but has increased since then.

Across all years, the mean number of excess age-adjusted deaths in mining relative to non-mining areas of Appalachia was 42.74 per 100,000. The population of the coal mining regions of Appalachia was 9,301,033, based on the mean of the U.S. Census figures for 1980, 1990, and 2000. Multiplying deaths per 100,000 (42.74) by the population in 100,000 units (93.01) resulted in an excess of 3,975 annualized deaths in coal mining areas of the region compared with the rest of Appalachia.

When we limited the analysis to the more recent period, 1997–2005, we found the number of excess annualized deaths to be 4,432. (This estimate used only the 2000 U.S. Census population for Appalachia to best match the mortality time period.) If mortality

rates in coal mining areas were equal to the nation outside Appalachia, the number of annualized averted deaths would be 8,840 for the period 1979–2005, and 10,923 for the period 1997–2005.

#### Covariate-adjusted mortality

Regression models examined two time periods: 1979–2005 and 1997–2005. For each time period, one model used national data and one was limited to Appalachian counties. The results of all four analyses indicated that higher age-adjusted mortality was independently related to coal mining counties in Appalachia after controlling for smoking rates, rural-urban location, percent male population, supply of primary care doctors, a regional South variable, poverty, race/ethnicity, and education. We selected these covariates to be consistent with other research on this topic.<sup>16–19</sup> We considered income and percentage of the population without health insurance, but then dropped them because of their high correlation with poverty. The covariates were themselves correlated with mortality. For example, we linked higher mortality with poverty, lower education, smoking, and higher percentages of African American and Native American populations.

The model for the national analysis across all years is summarized in Table 2; other models were similar. As shown, the coefficient for the mining effect after controlling for covariates was 31.06. Multiplied by the population of mining areas, this translated to 2,889 excess deaths. In other words, of the 8,840 excess age-adjusted deaths found in mining areas, 2,889 remained after accounting for smoking, race, poverty, physician

**Table 2. Regression model results<sup>a</sup> to estimate total age-adjusted mortality per 100,000 for 1979–2005 from mining, socioeconomic, and other variables: a national analysis**

Variable	Unstandardized coefficient	Standard error	P-value
Intercept	1,047.57	45.42	0.0001
Mining (yes/no)	31.06	7.46	0.0001
Appalachia (yes/no)	–2.57	4.96	0.6100
Smoking rate	3.08	0.44	0.0001
Rural-urban continuum code	–9.19	0.56	0.0001
Percent male population	–0.29	0.69	0.6800
Primary care physicians per 1,000	7.25	1.17	0.0001
South region of U.S. (yes/no)	24.01	4.04	0.0001
Poverty rate	5.24	0.41	0.0001
Percent African American	1.82	0.13	0.0001
Percent Native American	2.90	0.18	0.0001
Percent nonwhite Hispanic	–1.50	0.14	0.0001
Percent Asian American	–0.81	0.62	0.2000
Percent with high school education	–2.03	0.32	0.0001
Percent with college education	–3.34	0.28	0.0001

<sup>a</sup>Model F=355.67 (degree of freedom = 14, 3,125), *p*<0.0001; adjusted R<sup>2</sup> = 0.61

supply, education, and other variables. We also found this adjusted estimate for the number of excess deaths for the other three models, as shown in Table 3.

**Estimated costs and benefits of coal mining**

The assessment of the coal mining industry in Appalachia resulted in an estimate of the 1997 economic contribution valued at \$6.5 billion.<sup>32</sup> This estimate included direct, indirect, and induced earnings impacts. To the extent that employment in the mining industry has experienced a downward trend,<sup>43</sup> future declines in employment would reduce this impact estimate. Comparing the economic report with EIA figures<sup>25</sup> indicated an 11% decrease in employment in Appalachian coal mining from 1997 to 2005. We adjusted the impact estimate, which was based on employment figures, downward by 11% to account for this decrease in employment. However, we increased the estimate based on the mean 4.35% annual increase in the Consumer Price Index between 1997 and 2005. The resulting contribution of the coal mining industry in 2005 dollars may be estimated at \$7.798 billion. State income from coal severance taxes added about \$458 million to coal's economic contribution to the region in 2005 dollars, and tax credits reduced this amount by about \$168 million, for a final total of \$8.088 billion.

We used two VSL estimates: \$3.8 million and \$6.3 million per life.<sup>23</sup> We based these figures on 2000 dollars. Adjusting for the mean 4.60% annual increase in the Consumer Price Index between 2000 and 2005 resulted in VSL estimates of \$4.67 million and \$7.74 million expressed in 2005 dollars. Table 3 summarizes the estimates of the human cost of Appalachian coal mining by multiplying these VSL estimates with the estimates of excess deaths during varying time periods and comparison groups. The analysis is presented for

both unadjusted and adjusted deaths. In the unadjusted analysis, resulting estimates ranged from \$18.563 billion to \$84.544 billion, all of which were higher than the estimate of the beneficial economic impact of coal mining for the region. To identify a point estimate, we used the lower VSL estimate of \$4.67 million, selected the more recent time interval 1997–2005, and selected the mortality difference between coal mining areas and the nation based on the fact that the NIH goal is to equate health in Appalachia to the nation. Using this estimate, we determined the cost associated with coal mining in Appalachia as \$50.01 billion per year.

After adjusting for other mortality risks, the VSL analysis continued to show excess costs relative to the economic benefits of mining. Estimates ranged from \$8.236 billion to \$18.166 billion. In the case of adjusted estimates, using the higher EPA VSL figure of \$7.74 million was defensible because adjusted deaths more likely reflected environmental health impacts of mining; the resulting point estimate was \$18.166 billion per year.

**Discount analysis**

Table 4 summarizes the results of the discount analysis. This analysis used as the starting point the 2005 benefits of coal mining and the 1997–2005 estimate of excess deaths to reflect more current conditions. A 2% 10-year discount resulted in future VSL costs that exceeded current benefits for seven of eight scenarios. The only exception was for the smaller VSL that compared mining areas with other Appalachian areas adjusted for all covariates. Social disparity models indicated the importance of both socioeconomic and environmental variables and, therefore, the appropriateness of an unadjusted analysis: all four unadjusted results showed discounted VSL costs exceeding current benefits, with a point estimate

**Table 3. Unadjusted and adjusted costs of coal mining by VSL estimate and comparison group**

VSL	Cost estimates in billions for excess deaths in coal mining areas in comparison with other Appalachian counties and the nation, by time period			
	Appalachia, 1979–2005	Appalachia, 1997–2005	Nation, 1979–2005	Nation, 1997–2005
Unadjusted				
\$4.67 million	\$18.563	\$20.697	\$41.283	\$51.010
\$7.74 million	\$30.766	\$34.304	\$68.422	\$84.544
Number of excess unadjusted annual deaths	3,975	4,432	8,840	10,923
Adjusted				
\$4.67 million	\$8.236	\$8.491	\$13.492	\$10.923
\$7.74 million	\$13.646	\$14.071	\$22.361	\$18.166
Number of excess adjusted annual deaths	1,763	1,818	2,889	2,347

VSL = value of statistical life

**Table 4. Discounted VSL costs in billions of dollars based on a 10-year 2% discount rate<sup>a</sup>**

<i>Discounted VSL</i>	<i>Cost in billions compared with Appalachia</i>		<i>Cost in billions compared with the nation</i>	
	<i>Unadjusted</i>	<i>Adjusted</i>	<i>Unadjusted</i>	<i>Adjusted</i>
\$3.83 million	\$16.979	\$6.965	\$41.846	\$8.991
\$6.35 million	\$28.141	\$11.543	\$69.356	\$14.902

<sup>a</sup>Results are for two VSL estimates, for adjusted and unadjusted effects, and for comparisons with non-mining Appalachia and the nation.

VSL = value of statistical life

of \$41.846 billion under the same assumptions used to select the non-discounted point estimate.

## DISCUSSION

Age-adjusted mortality rates were higher every year from 1979 through 2005 in Appalachian coal mining areas compared with other areas of Appalachia or the nation. We found the highest mortality rates in areas with the highest levels of mining. Over time, the gap in mortality rates between coal mining areas and other areas of Appalachia and the nation has increased. The disparity became particularly noticeable after 1996. Consistent with social disparities models,<sup>13,14</sup> the results of the current regression analyses and other research suggest that poverty, low education level, smoking behavior, and environmental pollutants are among the factors that lead to higher mortality rates in coal mining areas.<sup>15,18,19</sup> Higher mortality may also be due in part to conditions of elevated stress<sup>44</sup> caused by economic disadvantage and environmental degradation. The results suggest, but do not prove, that a coal mining-dependent economy is the source of these continuing socioeconomic and health disparities. The call by NIH for research to reduce and eliminate Appalachian health disparities should focus on eliminating disparities in the coalfields.

Previous research that examined specific forms of mortality in coal mining areas found that chronic forms of heart, respiratory, and kidney disease, as well as lung cancer, remained elevated after adjusting for socioeconomic and behavioral factors.<sup>16,18,19</sup> Elevated adjusted mortality occurred in both males and females, suggesting that the effects were not due to occupational exposure, as almost all coal miners are men. These illnesses are consistent with a hypothesis of exposure to water and air pollution from mining activities. There is evidence that the coal mining industry is a significant source of both air and water pollution.<sup>45–50</sup> In the current study, the adjusted VSL costs indicate that the potential environmental impacts of mining exceed the economic benefits of mining.

Eliminating the mortality disparity in coal mining areas would result in savings of an estimated 3,975 to 10,923 lives per year based on choice of comparison group. The results of the unadjusted analysis showed that the corresponding VSL estimates outweighed the economic benefits of coal mining by up to an order of magnitude, and the point estimate outweighed the benefits of mining by a factor of six.

Discounting the majority of VSL costs 10 years into the future still resulted in costs that exceeded benefits in seven of eight tests. Social disparities models indicated that socioeconomic disadvantage should not be “adjusted away”; all four unadjusted tests showed future costs exceeding current benefits.

Socioeconomic disadvantage is a powerful cause of morbidity and premature mortality.<sup>51–53</sup> Coal mining regions have higher unemployment and poverty rates compared with the rest of Appalachia or the nation, and this economic disadvantage appears to be a contributing factor to the poor health of the region’s population. Areas with especially heavy mining have the highest unemployment rates in the region, contrary to the common perception that mining contributes to overall employment. The weakness of local coal-dependent economies is also evident from census data showing that migration has resulted in population loss from mining areas relative to non-mining areas. For example, coal mining counties in West Virginia experienced a mean net loss of 639 people to migration between 1995 and 2000, compared with a mean net migration gain of 422 people in non-mining counties.<sup>54</sup>

We limited the calculation of costs and benefits to those occurring in the Appalachian mining industry. For example, we did not include benefits such as the economic productivity resulting from coal combustion in factories nor the costs of premature deaths from air pollution caused by burning coal in those factories.<sup>39</sup> We intentionally limited the analysis to an assessment of the costs and benefits of the coal mining industry for the people of Appalachia.

We selected the VSL estimates that we used from studies by government agencies to reflect costs and

benefits of policies for the population at large. We excluded VSL estimates derived from labor market studies, which typically result in higher mean VSLs for working-age populations, so that all people, regardless of age, were included at equal value. Although studies have generally confirmed that the VSL declines with age, regulatory policies to improve environmental health also have disproportionate benefits for the elderly.<sup>23</sup> The U.S. federal government has established that age discrimination (discounting the life value of older people) in VSL estimates is contrary to official policy.<sup>22</sup>

### Limitations

First, despite the significant associations between coal mining activity and both socioeconomic disadvantage and premature mortality, it cannot be stated with certainty that coal mining causes these problems. It is not possible to determine what the economic and public health outcomes would be in these areas in the absence of mining. However, given the literature on the impacts of social disparities and the previously documented problems of coal-dependent economies, such a causal link seems likely.

Second, we had no direct measures of environmental pollutants to determine what role they play in excess mortality. We concluded that such an impact was possible given the results of the regression models and previously cited literature on the environmental consequences of coal mining.

Third, the discount analysis contained uncertainties. It was difficult to understand the time lag and the appropriate discount rate to apply to account for an unknown proportion of excess mortality due to delayed effects given available data.

Finally, the cost estimates may be conservative because they do not consider reduced employment productivity resulting from medical illness, increased public expenditures for programs such as food stamps and Medicaid,<sup>32</sup> reduced property values associated with mining activities,<sup>55</sup> and the costs of natural resource destruction.<sup>56</sup> Natural resources such as forests and streams have substantial economic value when they are left intact,<sup>57</sup> and mining is highly destructive of these resources. For example, Appalachian coal mining permanently buried 724 stream miles between 1985 and 2001 through mountaintop removal mining and subsequent valley fills, and will ultimately impact more than 1.4 million acres.<sup>58</sup> Coal generates inexpensive electricity, but not as inexpensive as the price signals indicate because those prices do not include the costs to human health and productivity, and the costs of natural resource destruction.

### CONCLUSIONS

In response to this and other research showing the disadvantages of poor economic diversification,<sup>2</sup> it seems prudent to examine how more diverse employment opportunities for the region could be developed as a means to reduce socioeconomic and environmental disparities and thereby improve public health. Potential alternative employment opportunities include development of renewable energy from wind, solar, biofuel, geothermal, or hydropower sources; sustainable timber; small-scale agriculture; outdoor or culturally oriented tourism; technology; and ecosystem restoration.<sup>10,59</sup> The need to develop alternative economies becomes even more important when we realize that coal reserves throughout most of Appalachia are projected to peak and then enter permanent decline in about 20 years.<sup>60</sup>

Various efforts have been proposed to reduce carbon dioxide emissions to combat climate change. However, tighter pollution emission standards, carbon tax, cap-and-trade, and carbon sequestration proposals, even if effective, will only address how coal is burned. Such proposals ignore how coal is extracted, processed, and transported prior to burning. These preconsumption processes carry their own significant economic, environmental, and health costs.

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# Relations Between Health Indicators and Residential Proximity to Coal Mining in West Virginia

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We used data from a survey of 16 493 West Virginians merged with county-level coal production and other covariates to investigate the relations between health indicators and residential proximity to coal mining. Results of hierarchical analyses indicated that high levels of coal production were associated with worse adjusted health status and with higher rates of cardiopulmonary disease, chronic obstructive pulmonary disease, hypertension, lung disease, and kidney disease. Research is recommended to ascertain the mechanisms, magnitude, and consequences of a community coal-mining exposure effect. (*Am J Public Health*. 2008;98:669–671. doi:10.2105/AJPH.2007.113472)

The United States has 27% of known coal reserves,<sup>1</sup> and as many as 153 new coal-fired power plants are scheduled for operation by 2030.<sup>2,3</sup> Pressure to increase coal mining is likely to intensify because of concerns about nuclear power, energy security, and peak global oil production.<sup>4–6</sup> Increased coal demand may exacerbate negative health effects of coal-mining activities, including occupational hazards of coal mining,<sup>7,8</sup> air pollution from burning coal,<sup>9</sup> health consequences of carbon dioxide–caused climate change,<sup>10,11</sup> and community exposure to mining activities. We examined whether coal mining in West Virginia is related to poorer health status and incidence of chronic illness. We sought to find whether coal mining effects may result only from socioeconomic correlates of mining such as income or education or whether effects persist after controlling for such factors,

which would suggest possible environmental exposure problems.

Quantitative research on health consequences of residential proximity to coal mining is limited to a few studies of respiratory illness conducted in Great Britain. One study found no effect of coal mining,<sup>12</sup> but others found elevated risks.<sup>13–15</sup>

## METHODS

In 2001, the West Virginia University Institute for Health Policy Research conducted a telephone survey of adults 19 years and older (N = 16 493; minimum number per county = 235). The response rate was 55%. We used 2000 US Census data to weight survey respondents to match the age, gender, income, education, and insurance status demographics of the state.

TABLE 1—Health Status and Rates of Disease Among Adults (N = 16 493), by County Coal Production Levels: West Virginia, 2001

	County Coal Production <sup>a</sup>			P	Bonferroni P
	0 Tons	≤3.9 Million Tons	≥4.0 Million Tons		
Health status, <sup>b</sup> mean score	2.62	2.68	2.85	<.001	.002
Any cardiopulmonary disease, %	13.5	13.8	15.9	<.001	.007
Lung disease, %					
Any lung disease	4.2	4.6	5.7	<.001	.007
Chronic obstructive pulmonary disease	1.6	1.5	2.1	.05	.85
Asthma	2.6	2.6	3.1	.27	.999
Black lung	0.3	0.7	0.8	<.001	.003
Heart disease or stroke, %					
Any heart disease	10.4	10.6	12.3	.004	.068
Hypertension	5.6	5.5	7.6	<.001	.002
Congestive heart failure	0.9	0.7	0.6	.17	.999
Arteriosclerosis	0.3	0.4	0.3	.57	.999
Cardiovascular disease	1.3	1.2	1.4	.90	.999
Stroke	0.5	0.4	0.6	.41	.999
Angina or coronary disease	5.4	5.6	5.4	.87	.999
Diabetes, %	6.2	5.7	7.0	.043	.73
Kidney disease, %	0.4	0.4	1.0	<.001	.002
Cancer, %	2.3	1.8	2.2	.26	.999
Arthritis or osteoporosis, %	5.5	5.4	6.4	.069	.999

<sup>a</sup>The division of coal production at 4 million tons groups coal-producing counties approximately in half. The effects of coal production on health are usually still present when the division occurs at 3 million tons or 2 million tons, but a division at 4 million tons resulted in a better fit of observed-to-expected level 2 residuals in the Table 2 hierarchical models. The category "≤3.9 million tons" does not include 0 tons as a measure.

<sup>b</sup>Score was based on self-reported health (1 = "excellent"; 6 = "very poor").

Dependent variables included self-reported health (scored 1 = "excellent" to 6 = "very poor") and the presence or absence of specific chronic health conditions.

We obtained 2001 coal production figures from the West Virginia Geological and Economic Survey,<sup>16</sup> including the short tons of coal mined from each county in both underground and surface mines. Coal production was not normally distributed, so we divided county coal production into 3 dummy variables: (1) no production, (2) up to 3.9 million tons, and (3) 4.0 million tons or greater.

County-level covariates included smoking and obesity rates from the West Virginia Department of Health and Human Resources, percentage of the population below the poverty level from US census data, and a measure of social capital.<sup>17</sup> Person-level covariates included age, gender, income,

education, and presence or absence of health insurance.

We analyzed whether health measures were associated with unadjusted coal production categories. Then we examined whether coal effects persisted after accounting for other person- and county-level variables with person-level HLM 6.03<sup>18</sup> multi-level modeling: linear modeling for health status and nonlinear REML Bernoulli modeling for the dichotomous presence of chronic illness. The intercept effect was random, and other effects were fixed. Results are reported for final population estimates with robust standard errors.

## RESULTS

As coal production increased, health status worsened, and rates of cardiopulmonary disease, lung disease, cardiovascular disease, diabetes, and kidney disease increased (Table 1). Within larger disease categories, specific types of disease associated with coal production included chronic obstructive pulmonary disease (COPD), black lung disease, and hypertension.

Dependent variables at  $P < .10$  from Table 1 (non-Bonferroni corrected) were carried forward for the multilevel analyses (Table 2). The highest level of mining ( $\geq 4.0$  million tons) predicted greater adjusted risk for cardiopulmonary disease, lung disease, hypertension, black lung disease, COPD, kidney disease, and poorer adjusted health status.

We considered the possibility that results reflected current or former coal miners living in the area. Almost all coal miners are men. The finding for black lung disease likely reflects a miner's effect, supported by the result that women are at lower risk. The only other illness for which men as a group had higher risk was the general cardiopulmonary category. We conducted an additional multilevel model (results not shown) separately for women for this category; the effects of the coal production variable remained significant.

## DISCUSSION

Among West Virginia adults, residential proximity to heavy coal production was

**TABLE 2—Hierarchical Model Results for Health Status and Rates of Disease Among Adults (N = 16 493): West Virginia, 2001**

Model	Coal Variables Only <sup>a</sup>	Full Models <sup>b</sup>
Worse health status, <sup>c</sup> b (SE)		
≤ 3.9 million tons of coal	0.057 (0.052)	0.024 (0.039)
≥ 4.0 million tons of coal	0.205 (0.066)	0.094 (0.032)
Cardiopulmonary disease, OR (95% CI)		
≤ 3.9 million tons of coal	1.029 (0.924, 1.147)	1.006 (0.910, 1.113)
≥ 4.0 million tons of coal	1.204 (1.033, 1.405)	1.119 (1.002, 1.249)
Lung disease, OR (95% CI)		
≤ 3.9 million tons of coal	1.117 (0.931, 1.340)	1.085 (0.904, 1.303)
≥ 4.0 million tons of coal	1.385 (1.138, 1.685)	1.297 (1.048, 1.605)
Chronic obstructive pulmonary disease, OR (95% CI)		
≤ 3.9 million tons of coal	0.969 (0.596, 1.577)	0.909 (0.582, 1.419)
≥ 4.0 million tons of coal	1.559 (1.069, 2.272)	1.637 (1.061, 2.526)
Black lung or external agent, OR (95% CI)		
≤ 3.9 million tons of coal	2.256 (1.273, 3.998)	2.254 (1.255, 4.047)
≥ 4.0 million tons of coal	2.608 (1.548, 4.392)	2.655 (1.602, 4.402)
Cardiovascular disease, OR (95% CI)		
≤ 3.9 million tons of coal	1.016 (0.908, 1.137)	0.994 (0.890, 1.110)
≥ 4.0 million tons of coal	1.186 (1.016, 1.384)	1.106 (0.990, 1.236)
Hypertension, OR (95% CI)		
≤ 3.9 million tons of coal	0.967 (0.826, 1.133)	0.956 (0.820, 1.116)
≥ 4.0 million tons of coal	1.371 (1.153, 1.631)	1.299 (1.130, 1.493)
Kidney disease, OR (95% CI)		
≤ 3.9 million tons of coal	0.792 (0.420, 1.495)	0.764 (0.397, 1.470)
≥ 4.0 million tons of coal	2.147 (1.371, 3.362)	1.698 (1.016, 2.837)
Diabetes, OR (95% CI)		
≤ 3.9 million tons of coal	0.928 (0.807, 1.068)	0.898 (0.773, 1.042)
≥ 4.0 million tons of coal	1.135 (0.911, 1.414)	1.008 (0.864, 1.176)
Arthritis or osteoporosis, OR (95% CI)		
≤ 3.9 million tons of coal	1.030 (0.878, 1.210)	0.994 (0.844, 1.170)
≥ 4.0 million tons of coal	1.233 (1.021, 1.488)	1.097 (0.901, 1.335)

Note. OR = odds ratio; CI = confidence interval. The category "≤ 3.9 million tons" excludes 0 tons as a measure.

<sup>a</sup>Includes only the 2 level-2 dummy variables measuring tons of coal mined, where zero coal mined is the reference category. Fifty-five counties were measured.

<sup>b</sup>Full models include adjustment for respondent age (19–25, 26–34, 35–44, 45–54, 55–64, 65–74, ≥ 75 years), gender, income (< \$30 000, ≥ \$30 000), education (less than high school, high school, some college, college graduate or higher), health insurance (yes or no), county poverty rate, smoking rate, obesity rate, and social capital. Other analyses not shown here explored various ways to categorize age and income, with no substantive effects on results. Analyses also were conducted limited to persons 45 years and older, and coal effects persisted for all response variables except kidney disease. N = 16 493 for level-1 variables and 55 for level-2 variables.

<sup>c</sup>Score was based on self-reported health (1 = "excellent"; 6 = "very poor"). For the coal-only model, the ≥ 4.0 million tons variable is significant at  $P < .004$ ; for the full model, it is significant at  $P < .005$ .

associated with poorer health status and with higher risk for cardiopulmonary disease, chronic lung disease, hypertension, and kidney disease, after we controlled for covariates.

Limitations of the study included the ecological design and the possibility that unmeasured variables confounded with coal mining,

such as individual smoking behavior or occupational exposure, contributed to poorer health. Second, the survey response rate was imperfect, potentially limiting generalizability, although responses were weighted to census data. Third, county of residence provides an imperfect estimate of people's

proximity to mining sites. Fourth, the format of the chronic disease questions likely resulted in an underreporting of disease. Fifth, the nonspecific cancer measure may have been too crude to detect effects, if they existed. The third through fifth limitations may have resulted in underestimating coal-mining effects.

For illnesses that were associated with coal effects, the literature supports the hypothesis that the risk for these illnesses increases with exposure to coal byproducts. Toxins and impurities present in coal have been linked to kidney disease<sup>19-23</sup> and to hypertension and other cardiovascular disease.<sup>24-28</sup> The effects also may result from the general inflammatory or systemic consequences of inhaled particles.<sup>29</sup> Effects may be multifactorial, a result of slurry holdings that leach toxins into drinking water<sup>30</sup> and air pollution effects of coal mining and washing.<sup>15,31,32</sup>

Our study serves as a screening test to examine whether coal mining poses a health risk for adults living near the mining sites. Confirmatory tests should be undertaken to establish mechanisms of action, magnitude, and health consequences of an exposure effect. ■

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## Contributors

M. Hendryx originated the study, collected and analyzed the data, and led the writing of the brief. M.M. Ahern contributed to study conceptualization, analyses, and writing.

## Human Participant Protection

This was an analysis of anonymous, secondary data sources, and institutional review board approval was not required.

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# Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia

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## Abstract

**Purpose** The purpose of this study was to test whether population mortality rates from heart, respiratory and kidney disease were higher as a function of levels of Appalachian coal mining after control for other disease risk factors.

**Methods** The study investigated county-level, age-adjusted mortality rates for the years 2000–2004 for heart, respiratory and kidney disease in relation to tons of coal mined. Four groups of counties were compared: Appalachian counties with more than 4 million tons of coal mined from 2000 to 2004; Appalachian counties with mining at less than 4 million tons, non-Appalachian counties with coal mining, and other non-coal mining counties across the nation. Forms of chronic illness were contrasted with acute illness. Poisson regression models were analyzed separately for male and female mortality rates. Covariates included percent male population, college and high school education rates, poverty rates, race/ethnicity rates, primary care physician supply, rural-urban status, smoking rates and a Southern regional variable.

**Results** For both males and females, mortality rates in Appalachian counties with the highest level of coal mining were significantly higher relative to non-mining areas for chronic heart, respiratory and kidney disease, but were not higher for acute forms of illness. Higher rates of acute heart and respiratory mortality were found for non-Appalachian coal mining counties.

**Conclusions** Higher chronic heart, respiratory and kidney disease mortality in coal mining areas may partially reflect environmental exposure to particulate matter or toxic agents present in coal and released in its mining and processing. Differences between Appalachian and non-Appalachian areas may reflect different mining practices, population demographics, or mortality coding variability.

**Keywords** Heart disease · Respiratory disease · Kidney disease · Mortality · Coal mining · Appalachia

## Introduction

Exposure to environmental pollutants increases risks for heart, respiratory and kidney disease. For example, low levels of environmental lead exposure accelerate progressive renal insufficiency in patients with chronic kidney disease (Lin et al. 2006), and environmental lead increases cardiovascular mortality in the general population (Menke et al. 2006). Mercury from industrial activity has been linked to kidney disease mortality (Hodgson et al. 2007). Arsenic in drinking water increases mortality from cardiovascular and kidney disease (Meliker et al. 2007). Cadmium exposure increases risk of renal dysfunction (Nishijo et al. 2006; Noonan et al. 2002). In addition to toxic agents, particulate matter (PM) from fossil fuel combustion increases risks for cardiovascular and respiratory disease morbidity and mortality (Barnett et al. 2006; Miller et al. 2007; Pope et al. 2002; Sarnat et al. 2006; Wellenius et al. 2006).

Appalachia is the mountainous, largely rural area in the eastern United States consisting of 417 counties and independent cities in 13 states. Previous research has identified that rates of cardiovascular, respiratory, and total mortality are higher in Appalachia compared to the rest of the country

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(Barnett et al. 1998, 2000; Cakmak et al. 2006; Halverson et al. 2004). Furthermore, heart disease mortality in Appalachia is higher in rural areas of the region compared to metropolitan areas (Barnett et al. 1998). Comparative rates for kidney disease have not been reported. Higher mortality rates in Appalachia are believed to result from higher smoking rates, poor dietary and exercise habits, and the correlates of poor socioeconomic conditions characteristic of the region such as limited access to health care.

However, another potential impact on the health of the population may originate from the environmental impacts of Appalachian coal mining. Coal mining constitutes a major industrial activity for eight Appalachian states (Alabama, Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia), where 390 million tons were mined in 2004 (Frema 2005). Residents of Appalachian coal mining communities report exposure to contaminated air and water from coal mining activities and express concerns for resulting illnesses (Goodell 2006), but empirical evidence on community health risks from coal mining activities is limited (Brabin et al. 1994; Hendryx and Ahern 2007; Hendryx et al. 2007, 2008; Higgins et al. 1969; Temple and Sykes 1992). Coal contains toxic impurities including zinc, cadmium, lead, mercury, arsenic and many others (WVGES 2007), and the mining and cleaning of coal at local processing sites creates large quantities of ambient particulate matter and contaminated water (Ghose and Banerjee 1995; Ghose and Majee 2000; Orem 2007; Stout and Papillo 2004). Not only toxic impurities, but the particulate matter from coal itself released into air or water during mining or processing may be a health hazard. Shiber (2005) reports elevated arsenic levels in drinking water sources in coal mining areas of central Appalachia, and McAuley and Kozar (2006) report that groundwater from sampled domestic wells near reclaimed surface coal mines, compared to wells in unmined areas, has higher levels of mine-drainage constituents including aluminum, iron, manganese, and others. It should be noted, however, that the chemical composition of coal slurry is largely undefined (Orem 2007) and that arsenic and other elements may result from various sources and may be present even in areas where no coal mining takes place. The objective of the current study was to determine whether heart, lung and kidney disease mortality rates in Appalachia are attributable to smoking, poverty, education, and other demographics, or whether there is an additional effect linked to residence in coal mining areas.

## Methods

This study investigated mortality rates for the years 2000–2004 for heart, respiratory and kidney disease. The study is an analysis of anonymous, secondary data sources and met

university Internal Review Board standards for an exemption from human subjects review.

Mortality data were obtained from the Centers for Disease Control and Prevention (CDC). These data measure county-level mortality rates per 100,000 population, age-adjusted using the 2000 US standard population (CDC 2007b). Disease categories were based on ICD-113 Groups provided by the CDC, which were cross-walked to ICD-10 Codes (The ICD-10 codes are provided in the parentheses in the Table 1 footnote). Diseases were grouped into acute or chronic conditions as shown in Table 1. Specifically excluded were codes for “pneumoconioses and chemical effects”, and “pneumonitis due to solids and liquids”, as these are established as occupational hazards related to coal mining, rather than potential population risks. Also excluded were several low-incidence categories for “other” or “unspecified” forms of disease or other low-incidence mortality causes. Because most coal miners are men, mortality rates were investigated separately for males and females to test the hypothesis that mining effects would be present for both sexes; support of this hypothesis suggests that results are not attributable to occupational exposure.

Coal production data were obtained from the energy information administration (Frema 2001, 2002, 2003, 2004, 2005). Production was measured as tons of coal mined in the county in both surface and underground mines. Analyses divided Appalachian coal mining into two levels: up to 4 million tons, and more than 4 million tons for the years 2000–2004. The choice of 4 million tons divided the number of coal mining counties approximately in half. Because the focus in this paper is on Appalachian coal mining, 97 non-Appalachian counties where coal mining took place were included as a separate category.

Covariates were taken from the 2005 Area Resource File (ARF 2006), CDC BRFSS smoking rate data (CDC 2007a), and the Appalachian Regional Commission (ARC 2007). Selection of covariates was based on previously identified risk factors or correlates of heart, respiratory or kidney disease (Barnett and Halverson 2001; Barnett et al. 2000; Hoffman and Paradise 2007; Iverson et al. 2005; Jones-Burton et al. 2007; Kunitz and Pesis-Katz 2005; Mannino and Buist 2007; Murray et al. 2005; Ziembroski and Brieding 2006). Covariates included percent male population, college and high school education rates, poverty rates, race/ethnicity rates, health uninsurance rates, physician supply, rural–urban continuum code, smoking rates, and Southern state (yes or no). Specific race/ethnicity groups included percent of the population who were African American, Native American, Non-white Hispanic, and Asian American (using White as the referent category in regression models). Rural–urban continuum was scored on a nine-point scale from least to most rural. Physician supply was the number of active MDs and DOs per 1,000 population. A

**Table 1** Descriptive summary of study variables by county category

	County category			
	No mining	Non-Appalachian mining	Appalachian mining ≤ 4 million tons	Appalachian mining > 4 million tons
Number of counties	2,914	97	66	63
Total population	274,502,126	4,234,505	5,287,206	3,762,685
Age-adjusted annual number of deaths				
Chronic heart disease <sup>a</sup>	303,319	9,948	7,421	8,550
Acute heart disease <sup>b</sup>	302,316	11,028	8,313	8,117
Chronic respiratory disease <sup>c</sup>	138,777	4,921	3,601	3,871
Acute respiratory disease <sup>d</sup>	67,513	2,423	1,726	1,639
Chronic kidney disease <sup>e</sup>	44,418	1,526	1,252	1,284
Acute kidney disease <sup>f</sup>	171	3	5	4
Covariates				
Smoking rate	23.0	24.0	27.7	29.2
Percent male	49.9	50.0	49.5	49.1
Percent African American	9.3	4.9	2.6	3.2
Percent Native American	1.9	4.9	0.2	0.2
Percent Hispanic	6.7	6.7	0.9	0.7
Percent Asian American	1.0	0.5	0.4	0.4
Percent with high school education	77.7	77.9	71.4	70.2
Percent with college education	16.8	14.8	12.3	11.5
Physicians per 1,000	1.3	1.2	1.3	1.5
Poverty rate	13.4	14.0	16.3	18.2
Percent Southern county	25.4	1.0	45.5	31.7
Mean urban–rural code	5.1	5.1	5.2	5.3

<sup>a</sup> Includes hypertensive heart disease (ICD-10 code I11), atherosclerotic cardiovascular disease so described (I25), all other forms of chronic, ischemic heart disease (I25.8), and essential (primary) hypertension and hypertensive renal disease (I10, I12)

<sup>b</sup> Includes acute myocardial infarction (I21), other acute ischemic heart diseases (I24), acute and sub-acute endocarditis (I33), diseases of pericardium and acute myocarditis (I31, I40), and heart failure (I50)

<sup>c</sup> Includes chronic and unspecified bronchitis (J40–J42), emphysema (J43), asthma (J45), and other chronic lower respiratory diseases (J44)

<sup>d</sup> Includes pneumonia (J12–J18), acute bronchitis and bronchiolitis (J20–J21), and unspecified acute lower respiratory infection (J22)

<sup>e</sup> Includes chronic glomerulonephritis, nephritis and nephropathy not specified as acute or chronic, and renal sclerosis unspecified (N03–N05), and renal failure (N17–N19)

<sup>f</sup> Includes acute and rapidly progressive nephritic and nephrotic syndrome (N00, N01)

dichotomous Southern variable was created to capture larger regional effects that partially overlap with Appalachia; Southern states included Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. CDC smoking rates were available for states and some county-based metropolitan areas. In an effort to improve smoking data, the state public health websites for all 50 states were reviewed and more specific county-level smoking rate data were found for 30 states, sometimes for individual counties and sometimes for groups of counties. The state average was used only when the more specific rate was not available. Appalachian counties included the 417 counties and independent cities in 13 states as defined by the Appalachian Regional Commission (ARC 2007).

Analyses were conducted using Poisson multiple regression with a log link function to test for the association between residence in coal mining areas and mortality rates with control for covariates. The primary independent variable of interest is a categorical measure of coal mining exposure with four levels: no coal mining, non-Appalachian mining, Appalachian mining up to 4 million tons, and Appalachian mining greater than 4 million tons.

## Results

Table 1 contains descriptive characteristics of the counties by the four exposure groupings: no mining, non-Appalachian mining, Appalachian mining up to 4 million tons, and

Appalachian mining greater than 4 million tons. Appalachia has higher smoking rates, higher poverty rates, and lower education levels, but smaller race/ethnicity minority populations, compared to the nation. Acute kidney disease was a rare cause of mortality, and therefore this mortality category was dropped from further analysis.

Bivariate correlations among independent variables were examined for multicollinearity. Two variables, poverty rate and percent without health insurance, were correlated at  $r = 0.81$ , and so the insurance rate variable was dropped from regression models.

The next steps of the analysis examined age-adjusted mortality rates, and tested whether there were mortality effects linked to coal mining after accounting for covariates. Age-adjusted rates before adjusting for covariates are shown in Tables 2 and 3 for males and females, respectively. Mortality rates are higher in Appalachian mining areas compared to other areas in every instance. Mortality rates for these conditions are higher for men than for women, but this is the case for both mining and non-mining areas.

Poisson regression model results adjusting for covariates are presented in Tables 2 and 3, one table each for males and females. The rate ratios (RR) were found after exponentiating the log values back to the original scale; these

figures represent the proportional increment in mortality rates per 100,000 relative to the non-mining reference category. For Appalachian mining areas, significantly higher mortality rates showed the same pattern for males and females. Among the Appalachian counties with the highest mining level, higher mortality rates were found for both males and females for total and chronic heart disease, total and chronic respiratory disease, and chronic kidney disease. Appalachian mining effects were stronger and more frequent in areas where mining was highest compared to areas of less-intense mining.

Coal mining areas outside Appalachia showed a similar but not identical pattern for males and females: for both sexes there were higher total and acute respiratory mortality, and higher acute heart disease mortality. Females, but not males, had significantly higher total heart disease mortality and chronic kidney disease mortality; males but not females had significantly higher mortality from chronic respiratory illness.

There were also instances where mortality was significantly lower than expected. For Appalachian coal mining areas, lower mortality was found for acute forms of heart and respiratory illness. In other words, higher mortality in Appalachian mining areas was specific to total and chronic forms of illness, while for non-Appalachian mining areas

**Table 2** Male age-adjusted mortality rates per 100,000 population by mining category with 95% confidence interval (CI) in parentheses, followed by rate ratios (RR) and 95% CI adjusted for all covariates with non-mining as the referent

	Appalachian mining > 4 million	Appalachian mining up to 4 million	Non-Appalachian mining	Non-mining
Total heart				
Age-adjusted mortality	331 (316–346)	298 (287–309)	270 (257–283)	261 (259–263)
RR	1.07 (1.05–1.09)	1.01 (0.99–1.02)	1.01 (0.99–1.02)	–
Chronic heart				
Age-adjusted mortality	171 (160–181)	139 (129–149)	127 (119–136)	130 (128–131)
RR	1.28 (1.25–1.30)	1.06 (1.04–1.08)	0.96 (0.94–0.98)	–
Acute heart				
Age-adjusted mortality	160 (145–175)	159 (146–172)	143 (133–153)	132 (130–134)
RR	0.89 (0.87–0.91)	0.95 (0.93–0.97)	1.06 (1.04–1.08)	–
Total respiratory				
Age-adjusted mortality	113 (104–121)	105 (98–113)	96 (92–100)	90 (89–91)
RR	1.03 (1.00–1.05)	0.97 (0.95–0.99)	1.05 (1.02–1.07)	–
Chronic respiratory				
Age-adjusted mortality	81 (75–87)	74 (69–79)	67 (64–71)	63 (62–64)
RR	1.07 (1.04–1.10)	0.99 (0.97–1.03)	1.04 (1.02–1.06)	–
Acute respiratory				
Age-adjusted mortality	32 (28–36)	31 (27–35)	28 (26–31)	28 (27–28)
RR	0.94 (0.89–0.98)	0.92 (0.88–0.96)	1.05 (1.01–1.09)	–
Chronic kidney				
Age-adjusted mortality	25 (23–27)	22 (20–24)	18 (17–20)	19 (18–19)
RR	1.19 (1.13–1.25)	1.10 (1.05–1.16)	1.02 (0.98–1.06)	–

**Table 3** Female age-adjusted mortality rates per 100,000 population by mining category with 95% confidence interval (CI) in parentheses, followed by rate ratios (RR) and 95% CI adjusted for all covariates with non-mining as the referent

	Appalachian mining > 4 million	Appalachian mining up to 4 million	Non-Appalachian mining	Non-mining
Total heart				
Age-adjusted mortality	213 (202–224)	192 (183–201)	174 (165–182)	165 (164–167)
RR	1.06 (1.04–1.08)	1.00 (0.98–1.02)	1.03 (1.02–1.05)	–
Chronic heart				
Age-adjusted mortality	109 (102–116)	92 (85–99)	83 (77–89)	84 (83–85)
RR	1.18 (1.15–1.21)	1.03 (1.00–1.05)	0.97 (0.95–0.99)	–
Acute heart				
Age-adjusted mortality	104 (94–114)	100 (92–108)	91 (85–96)	82 (80–83)
RR	0.95 (0.93–0.97)	0.97 (0.94–0.99)	1.10 (1.08–1.12)	–
Total respiratory				
Age-adjusted mortality	73 (68–78)	65 (61–70)	63 (59–66)	59 (58–59)
RR	1.03 (1.00–1.06)	0.94 (0.91–0.97)	1.05 (1.02–1.07)	–
Chronic respiratory				
Age-adjusted mortality	61 (57–66)	55 (51–58)	51 (48–53)	48 (47–48)
RR	1.11 (1.07–1.15)	0.94 (0.90–0.98)	1.01 (0.98–1.04)	–
Acute respiratory				
Age-adjusted mortality	26 (23–29)	26 (23–29)	25 (23–27)	23 (23–24)
RR	0.89 (0.84–0.94)	0.92 (0.87–0.97)	1.13 (1.08–1.18)	–
Chronic kidney				
Age-adjusted mortality	18 (16–19)	17 (16–19)	14 (13–15)	13 (13–14)
RR	1.13 (1.06–1.21)	1.14 (1.07–1.21)	1.08 (1.02–1.14)	–

mortality was elevated for acute heart and respiratory disease, and chronic kidney disease for females.

Finally, county-level coal mining data are reported for the nation by the Energy Information Administration only back to 1999. However, disease consequences of exposure are hypothesized to be long-term phenomena. Longer historical records of county-level coal mining are available on the websites of two state Geological Surveys, those for West Virginia and Kentucky; an examination of these sources indicated that 100% of counties categorized in the highest coal-mining group for the current study had high levels of coal mining extending back at least to 1986. Appalachian areas with large coal reserves have been mining coal for decades.

## Discussion

Total and chronic heart, respiratory and kidney disease mortality rates are significantly higher in coal mining areas of Appalachia compared to non-mining areas of the country. Coal mining industrial activities may expose residents to environmental contaminants, or these geographic areas may be associated with additional behavioral or demographic characteristics not captured through other covariates.

The same effects are found for both males and females in Appalachia.

The different pattern of results in coal mining areas outside Appalachia was not expected. The different results may reflect differences in population demographics, migration patterns, mining practices, geographic topography, or population density [i.e., the population density of Appalachian coal mining areas (118 per square mile) is significantly higher than non-Appalachian mining areas (64 per square mile)]. Differences may also reflect variation in medical diagnostic practices that favor acute or chronic classifications; when considering total mortality rates, mining areas inside and outside Appalachia were elevated compared to non-mining areas.

Limitations of the study include the reliance on secondary county-level data. Causes of individual mortality cannot be identified, and the precise pathway between residence in coal mining areas and mortality is unknown. The phenomenon of environmental exposure occurs at an aggregate level, and as there is a risk of an ecological fallacy, so is there a risk of an atomistic fallacy by failing to account for the aggregate nature of the effect (Willis et al. 2003). More definitive research should be conducted using multi-level modeling of aggregate ecologic impacts on individual outcomes. An additional critical next research step is to collect

direct air and water samples in coal mining communities to test the hypothesis that increased mortality from these chronic diseases is linked to poorer air and water quality.

Another limitation is the use of smoking rates that were imprecisely measured. Smoking effects, including exposure to second-hand smoke linked to poorer socioeconomic conditions, may be underestimated. The smoking variable, however, did predict higher mortality rates across conditions and so operated as expected.

Not all risk factors could be measured, for example, kidney disease risks associated with diabetes or hypertension were not assessed. Behaviors such as physical activity levels and alcohol consumption could not be included. Demographic or cultural variables not captured through available covariates may be contributing factors; these variables might include Appalachian cultural beliefs such as fatalism (Coyne et al. 2006) that increase risk for poor health behaviors or delay early health care intervention, or weak tobacco control policies that increase second-hand smoke exposure.

Future research should collect direct measures of smoking, occupational exposure, duration of environmental exposure, and individual-level health and disease measures to confirm the findings suggested by this research. Research to examine the different mortality patterns in Appalachian and non-Appalachian areas is indicated. Additional research is also needed to identify exposure types, levels, and mechanisms of action that can account for higher mortality in coal mining areas. For example, research can determine if pollution from mining itself is a contributing factor or whether the coal processing, cleaning and transportation activities that take place after mining are more important, and can determine through direct air and water quality monitoring if one transmission route or the other, or both, contribute to poor health outcomes. The pattern of results and prior research suggest that water quality may be a factor for kidney disease, that air quality may be a factor for respiratory disease, and that either air or water problems may be related to heart disease.

Until recently, research on the community health impacts of Appalachian coal mining had been unavailable, and only anecdotal evidence (Goodell 2006; Loeb 2007) attested to the health impacts of living in proximity to mining activities. A body of evidence is beginning to emerge, however, that confirms the beliefs of local residents at least to some extent, and suggests that coal mining-related community health problems are real (Hendryx and Ahern 2008; Hendryx et al. 2007, 2008; Orem 2007; Shiber 2005; Stout and Papillo 2004). As evidence accumulates to reveal a previously unknown contributing factor to the infamous health disparities plaguing Appalachia, it becomes critical to address issues of environmental equity and to reduce environmental and socioeconomic disparity through economic and policy interventions. These interventions may include

establishing and enforcing stricter air and water quality standards in coal mining communities.

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# A geographical information system-based analysis of cancer mortality and population exposure to coal mining activities in West Virginia, United States of America

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**Abstract.** Cancer incidence and mortality rates are high in West Virginia compared to the rest of the United States of America. Previous research has suggested that exposure to activities of the coal mining industry may contribute to elevated cancer mortality, although exposure measures have been limited. This study tests alternative specifications of exposure to mining activity to determine whether a measure based on location of mines, processing plants, coal slurry impoundments and underground slurry injection sites relative to population levels is superior to a previously-reported measure of exposure based on tons mined at the county level, in the prediction of age-adjusted cancer mortality rates. To this end, we utilize two geographical information system (GIS) techniques – exploratory spatial data analysis and inverse distance mapping – to construct new statistical analyses. Total, respiratory and “other” age-adjusted cancer mortality rates in West Virginia were found to be more highly associated with the GIS-exposure measure than the tonnage measure, before and after statistical control for smoking rates. The superior performance of the GIS measure, based on where people in the state live relative to mining activity, suggests that activities of the industry contribute to cancer mortality. Further confirmation of observed phenomena is necessary with person-level studies, but the results add to the body of evidence that coal mining poses environmental risks to population health in West Virginia.

**Keywords:** mining, coal, cancer, mortality, geographical information system, Virginia.

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## Introduction

Cancer mortality in West Virginia and other parts of Appalachia is high relative to the United States of America as a whole (Huang et al., 2002; Halverson et al., 2004; Wingo et al., 2008). The higher cancer mortality in the region has been attributed to behavioural risks such as smoking, poor socio-economic conditions and problematic

access to medical care (Huang et al., 2002). However, recent research evidence also points to the impact of the coal mining industry on population health. Persons who live in coal mining counties of Appalachia, compared to non-mining counties or the nation, have elevated all-cause (Hendryx, 2008; Hendryx and Ahern, 2009) and lung cancer (Hendryx et al., 2008) mortality, after controlling for socio-economic, health services and behavioural variables.

Coal contains many established carcinogens including arsenic, cadmium, chromium, nickel, beryllium and others (WVGES, 2007a), and coal extraction, processing and transportation activities have contaminated trillions of gallons of

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water (Todd, 2008) and released tons of particulate matter into the air near mining communities (Ghose, 2007). Previous studies of the effects of coal mining on community health have relied on the tons of coal mined at the county level as the exposure measure, which is then correlated to health outcomes, also usually at the county level (Hendryx, 2008, 2009; Hendryx et al., 2008). Although statistical controls are made for confounding factors such as race/ethnicity, smoking, education, physician supply, poverty and others, the results are still limited to this exposure measure and have not accounted for more specific activities of the mining industry in relation to population concentrations and health outcomes.

The purpose of the current study was to use geographic information systems (GIS) to develop and test a more refined measure of population exposure to components of the mining industry in West Virginia compared to the exposure measure used in previous studies, by relating the comparative exposure measures to cancer mortality. The more refined measure is a distance-weighted population exposure score, distance being distance to components of the mining industry, as described in the next section. If it is true that exposure to extraction and processing activities of the mining industry increases cancer risk among community residents, one would expect distance-weighted population exposure measures to be more highly correlated to cancer mortality rates than the previous measure of tons of county-level coal mining. If, on the other hand, cancer mortality is not causally related to exposure to mining activity, but reflects only socio-economic or behavioural confounds, there should be no improvement in the capacity of the exposure measure to account for mortality rates. We have tested the hypotheses that (i) age-adjusted county cancer mortality rates will be positively associated with distance-weighted population exposure to coal extraction and processing activities, and (ii) the distance-weighted exposure measure will be more strongly correlated to cancer mortality than exposure based on tons of coal mined in the county.

## Materials and methods

### *Study area*

This study focuses on one state within the Appalachian region, West Virginia. Uniquely among Appalachian states, all 55 of West Virginia's counties fall within the Appalachian region as defined by the Appalachian Regional Commission (ARC, 2007). US Census data indicate that the total population of West Virginia is slightly over 1.8 million people, 37<sup>th</sup> among all states (US Census 2009a, b).

West Virginia is largely rural. Of the 55 counties, eight are classified as "metropolitan" by the US Department of Agriculture (USDA) Economic Research Service's Urban Influence Coding system (ARE, 2006). With the exception of Jefferson county, which lies in the eastern panhandle close to Washington D.C., the major urban area of West Virginia is the Kanawha River Valley, in the southwestern part of the state. The seven counties in this valley contain the state's two largest cities – Charleston, the state capital, and Huntington. The remaining 47 counties are all classified as "non-metropolitan" and their respective codes cover the gamut from "micropolitan adjacent to large metro area" to "noncore adjacent to micro area, containing a town of 2,500–9,999 residents." In terms of population, the rural/urban dichotomy is reflected in the Census 2000 values. Approximately 50% of West Virginia's population resides within just 11 counties. Ten counties have less than 10,000 residents. West Virginia's counties have an average population density of 94.9 persons, and a median of 51.1 persons, per square land mile. When the county population density is mapped by natural breaks (JENKS) classification, 29 of West Virginia's 55 counties fall into the lowest value group.

West Virginia has a long history of coal mining as a principal industry. While most (if not all) West Virginia counties have been touched in some way by coal mining, most production has taken place within a few core areas. The coal infrastructure data utilized in this analysis is concerned with the location

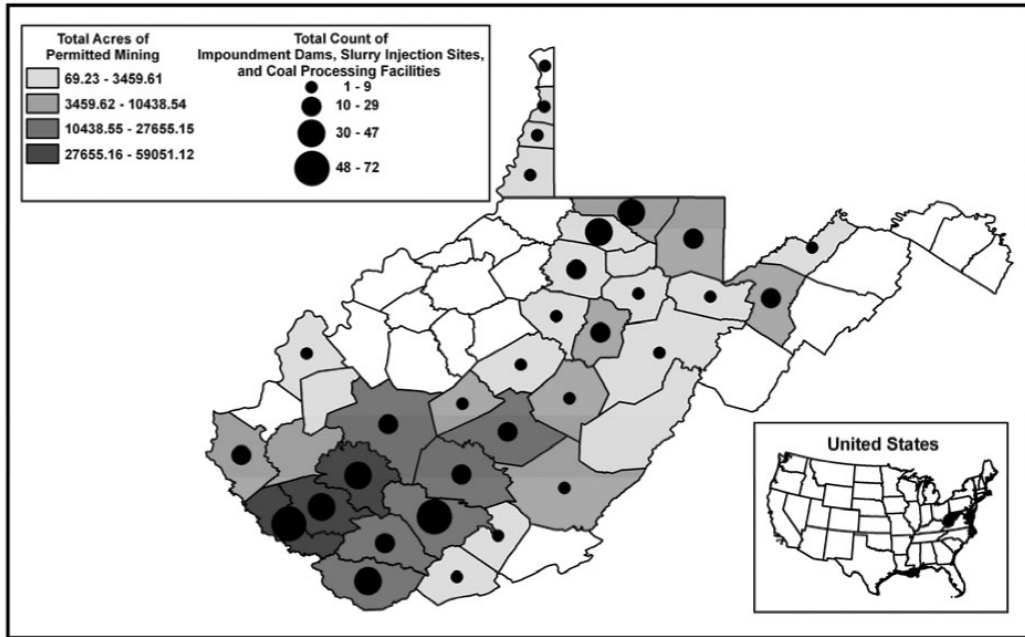


Fig. 1. West Virginia mining activities by count (1979-2004).

of various types of facilities (see the Data subsection below). As can be seen in Figure 1, these facilities are mostly located along a southeast (SW) to northeast (NE) trending band of counties through the central part of the state.

### Data

Cancer mortality rates were taken from the Centers for Disease Control and Prevention (CDC) (Atlanta, GA, USA) public data website (CDC, 2008). The rates are age-adjusted using the 2000 US standard population, and are found for West Virginia counties as the rate per 100,000 person-years for 1979-2004. The person-year approach allowed us to aggregate across years to estimate cancer mortality in rural, less populated counties that typify most coal mining locations. Based on International Classification of Disease (ICD)-9 (years 1979-1998) and ICD-10 (years 1999-2004) diagnostic classifications, mortality rates were found for digestive, genital, urinary, breast, oral, respiratory, other and combined cancer sites. These

are the major diagnostic classifications provided on the CDC data consistently across ICD-9 and ICD-10 specifications and represent the major body systems for which rates are reported. Table 1 summarises the diagnostic categories.

US Census data for the year 2000 were used to find the population of each census block group within the state. This dataset was acquired from a DVD of base layer geographic information of the United States of America. The DVD was published by Environmental Systems Research Institute (ESRI) (Redlands, CA, USA), but the dataset itself originates from the United States Census Bureau.

Potential county-level covariates were based on prior studies (Hendryx and Ahern, 2008; Hendryx et al., 2008.) The time period, represented by covariates, was sometimes based on the 2000 Census, and sometimes on more recent estimates when available. These covariates include average poverty rate for 2000-2002, high school and college education rates in 2000, supply of primary care physicians per 1,000 population in 2001, smoking rate in 2003, percent race/ethnicity categories as of

Table 1. ICD-9 (years 1979-1998) and ICD-10 (years 1999-2004) codes used to classify cancer mortality by site.

<i>ICD-9 Codes</i>	<i>ICD-9 Labels</i>	<i>ICD-10 Codes</i>	<i>ICD-10 Labels</i>
140-149	Lip, oral cavity and pharynx	C00-C14	Lip, oral cavity and pharynx
150-159	Digestive organs and peritoneum	C15; C16; C18-C21; C22; C25	Esophagus; stomach; colon, rectum and anus; liver and intrahepatic bile duct; pancreas
160-165	Respiratory and intrathoracic	C32; C33-C34	Larynx; trachea, bronchus and lung
174-175	Breast	C50	Breast
179-187	Genital organs	C61; C53; C54-C55; C56	Prostate (males); cervix uteri; corpus uteri and uterus; ovary (females)
188-189	Urinary organs	C64-C65; C67	Kidney and renal pelvis; bladder
200-203; 204-208; 170-173; 190-199	Other malignant neoplasms of lymphatic and hematopoietic tissue; leukemia; all other and unspecified	C81; C82-C85; C88-C90; C96; C91-C95; C43; C70-C72	Hodgkin's disease; non-Hodgkin's lymphoma; multiple myelomas and immunoproliferative neoplasms; other unspecified neoplasm of lymphoid hematopoietic and related tissue; leukemia; all other and unspecified

2002 (i.e. White, Native American, African American, Asian American, non-white Hispanic), 2000 rural-urban continuum code, health insurance rate in 2000, and percent female population in 2000. Data for most covariates were obtained from the Area Resource File (ARF, 2006). Smoking rates were taken from the CDC Behavioral Risk Factor Surveillance System (BRFSS) website (CDC, 2007) supplemented with examination of the state public health department website.

Geographic data on activities of the coal mining industry included mining permit boundaries for mining sites, the point locations of surface slurry impoundment dams, the point locations of permitted underground injection sites, and the point locations of coal processing facilities (preparation plants). Most of the data compilation and manipulation was performed using ArcView GIS software, versions 9.2 and 9.3 (ESRI, Redlands, CA, USA). Most datasets originate from the West Virginia Department of Environmental Protection (WVDEP), but in some cases, additional analysis has been undertaken. The WVDEP publishes a spatial database of mine permit boundaries within West Virginia via an internet website (<http://gis.wvdep.org/data/omr.html>) (WVDEP,

2009). For the purpose of this study, we removed permit boundary polygons whose permit dates did not interest the time period of interest – 1979 to 2004. In total, we included 2,924 mining boundaries in the study. It is important to note that these boundary areas can overlap and thus, it is difficult to count a single boundary area as a single mine as certain mine features – such as roads – are often reused and re-permitted in subsequent mining operations. Likewise, the measure of total acres of mining per county is best described as approximate given this reality and the inherent inaccuracies of the data and it's reflection of reality on the ground.

Mining operations often involve the capture of used water in artificial impoundments, held in place by earthen dams, for the purpose of removing contaminants and non-combustibles. Acid mine drainage (AMD) is also held in surface impoundments. These coal impoundment dams are also regulated by the WVDEP. According to WVDEP GIS management, the overall spatial accuracy of the coal impoundment dam dataset utilized in this study is high (M Shank, WVDEP, personal communication). The data are difficult to maintain, however, and as such, temporal accuracy is difficult to quantify, but assumed to be less than current. In our own explo-

rations of the data, we compared the points to 2003 aerial photography and found that most (115 points, or 84%) of the points align with a dam in existence as of that date. A few (22 points, or 16%) appear to be reclaimed, although health considerations from these prior impoundments may still be relevant. At this time we cannot assign a reclamation date to these points. We used all 137 coal impoundment dams in this study.

We identified two sources of spatial information for coal processing facilities. The first, derived from the US Environmental Protection Agency (EPA)'s facility registry system, appeared to be incomplete when compared to the data obtained from the WVDEP. In the end, we derived a subset of points from the WVDEP's point database of coal activities permits that pertained to coal processing facilities. We then performed a basic photo alignment of these features using 2003 aerial photography. Where possible, the point was relocated to a more accurate location. Of 76 entities, 46 were realigned in this way. The remaining 30, most of which had been reclaimed at the time of the aerial photography, remained in their originally published location.

The last coal mining feature utilized in this study is slurry injection site locations. These are areas where waste water from mining, drilling or processing has been injected into underground voids for the purpose of storage. These entities are permitted by the WVDEP as part of the mine process and the points at which they discharge (into a nearby stream or reservoir) are permitted by the EPA as National Pollution Discharge Elimination System (NPDES) points. The content of the slurry is monitored at the discharge points as part of the NPDES regulatory process. The data we use in this study were compiled from the WVDEP permit database and EPA NPDES database. This study did not differentiate between injection sites and discharge points. In total, the dataset contains 270 points.

The analysis was completed in three phases. First, we conducted an exploratory spatial data analysis (ESDA) to determine if, in fact, any quantifiable spatial relationships existed between our existing

data. Second, we developed a distance-based index describing, per county, the proximity of that county's population to coal mine features. Last, we utilized this index in a regression analysis, discussed in more detail in the "Analysis and Results" section.

### Analysis

The current ESDA of the association between coal extraction and processing activities and cancer mortality rates was conducted on census block group and county level data for West Virginia. GIS and its spatial analysis tools were used to examine the spatial association/autocorrelation between county-level age-adjusted combined cancer mortality rates and total tonnage of coal production per county. First, a global measure of spatial autocorrelation to measure the level and direction (e.g. positive or negative) of association for the entire sample was used. Here, we tested the hypothesis that the univariate and bivariate global measures result in positive spatial autocorrelation. If the variables of interest are found to have positive spatial autocorrelation, then their local statistics of spatial autocorrelation are calculated to identify where these spatial clusters exist.

Global spatial autocorrelation was used to test the overall spatial dependency of the variables of interest by calculating a Moran's  $I$  statistic. Moran's  $I$  is defined as:

$$I = \frac{\frac{N}{\sum_i \sum_j W_{ij}} \sum_i \sum_j W_{ij} Z_i Z_j}{\sum_i Z_i^2}$$

where  $Z_i$  is the deviation of the variable of interest with respect to the mean;  $W_{ij}$  the spatial weight matrix (i.e. a binary matrix with "ones" in position  $i, j$  whenever observation  $i$  is a neighbour of observation  $j$ , and otherwise "zero");  $N$  the number of observations and  $\sum_i \sum_j W_{ij}$  the standard deviation (Anselin, 1995). The resulting test is similar to a correlation coefficient as it varies between -1.0 and +1.0. This test of global spatial autocorrelation was computed using GeoDa 0.9.5-i software down-

loaded from Arizona State University's GeoDa Center.

The variables of interest, county-level age-adjusted combined cancer mortality rates (1979-2004) and tonnage of coal production per county (1986-2005), were joined to a georeferenced spatial county layer file of West Virginia and its first order (neighbouring) counties from surrounding states. The tonnage measure, rather than the distance-weighted measure, was used for the spatial analysis because we could capture tonnage measures from border counties outside West Virginia. However, the mapping of mining activities was available only within the state. The data were joined to the georeferenced spatial county layer file by their unique 5-digit federal information processing standards (FIPS) code. A spatial weight ( $W$ ) was then created to impose a neighbourhood structure on the data. We chose and created a queen contiguity weight matrix for each variable of interest.

We then calculated two univariate Global Moran's  $I$  statistics, one for the county-level age-adjusted combined cancer mortality rates (1979-2004) and one for the total tonnage of coal production per county (1986-2005). We also calculated a bivariate Global Moran's  $I$  statistic with the total tonnage of coal production per county (1986-2005) along the X-axis and the county-level age-adjusted combined cancer mortality rates (1979-2004) along the Y-axis. Lastly, we randomized each Global Moran's  $I$  statistic by 999 random permutations to yield a pseudo p-value. Finally, we interpreted Moran's  $I$  by whether the values of  $I$  were significantly greater than the expected values (positive spatial autocorrelation) or significantly less than the expected values (negative spatial autocorrelation).

The local indicators of spatial autocorrelation (LISA) statistic has been described, in the words of Anselin (1998), as "an indicator that achieves two objectives: it allows for the detection of significant patterns of local spatial association (i.e. association around individual location), and it can be used as a test for stability of a global diagnostic (i.e. to assess

the extent to which the global pattern of association is reflected uniformly throughout the data set".

This local Moran's  $I$  statistic is derived from the Global Moran's  $I$  statistic by the formula:

$$I = \frac{Z_i}{m_2} \sum_j W_{ij} Z_j, \text{ where}$$

$$m_2 = \sum_i Z_i^2, \text{ hence}$$

$$I = \sum_i \frac{I_i}{N},$$

where  $N$  is the number of observations (Anselin, 1995). The current LISA analysis is identical to the global spatial autocorrelation analysis in software, data, spatial weight matrix, number of tests and permutations. However, this analysis results in the production of a 95% level of significance cluster map, which classifies four different cluster types: high-high, low-low, low-high and high-low (Anselin, 2003). The high-high and low-low clusters suggest areas where similar values are clustered together indicating positive spatial autocorrelation, while low-high and high-low clusters indicate spatial outliers and negative spatial autocorrelation (Anselin, 2003; GeoDa Center, 2009).

#### *Distance-weighted at-risk population index*

The results of the ESDA indicate that a quantifiable relationship between population proximity to coal mine features and cancers exists (see the "Analysis and Results" section). We were presented with a challenge at this point: although we are fortunate to have access to point data that precisely locate coal mine features, our cancer rate information remained at a coarse county-level resolution. We opted to create a simple distance-based statistic using the finest scale data available which could then be summed at the county level. While the potential exposure variable would still be coarse, the finer scale of the source data should enhance the analysis and allow for a test of the primary study

hypothesis. We opted to utilize distance to account for the potential fallacies that exist when quantifying exposure based on counting facilities based on arbitrary boundaries (Maantay, 2002).

We developed the refined exposure index using simple GIS techniques, the main steps of which are illustrated in Figure 2. As described above, the polygon location of every coal mine was mapped, along with the point location of every coal preparation plant, slurry impoundment dam, and permitted underground slurry injection site. Next, we determined Euclidean distance from each of the coal mining infrastructure entities via 30x30 m grid cell distance measures. Within each of the study area's census block groups, we calculated the mean distance in km from each to the nearest (i) mine boundary poly-

gon, (ii) impoundment dam centroid, (iii) injection site, and (iv) preparation plant (Fig. 2, step 1). We then found the inverse distance ( $1/\text{distance}$ ) for each mine infrastructure type for each block group. The mean inverse distances were multiplied by the population of the block group. This results in a value per block group/infrastructure type wherein closer distances and bigger populations have larger values, and farther distances and smaller populations have smaller values (step 2).

These values are representative of a population "P" variable adjusted by inverse distance as a metric of exposure. These values were summed across type "t" (mine "m", impoundment dam "d", injection site "I", and preparation plant "p") (step 3) and across block group "k" to the county-level (step

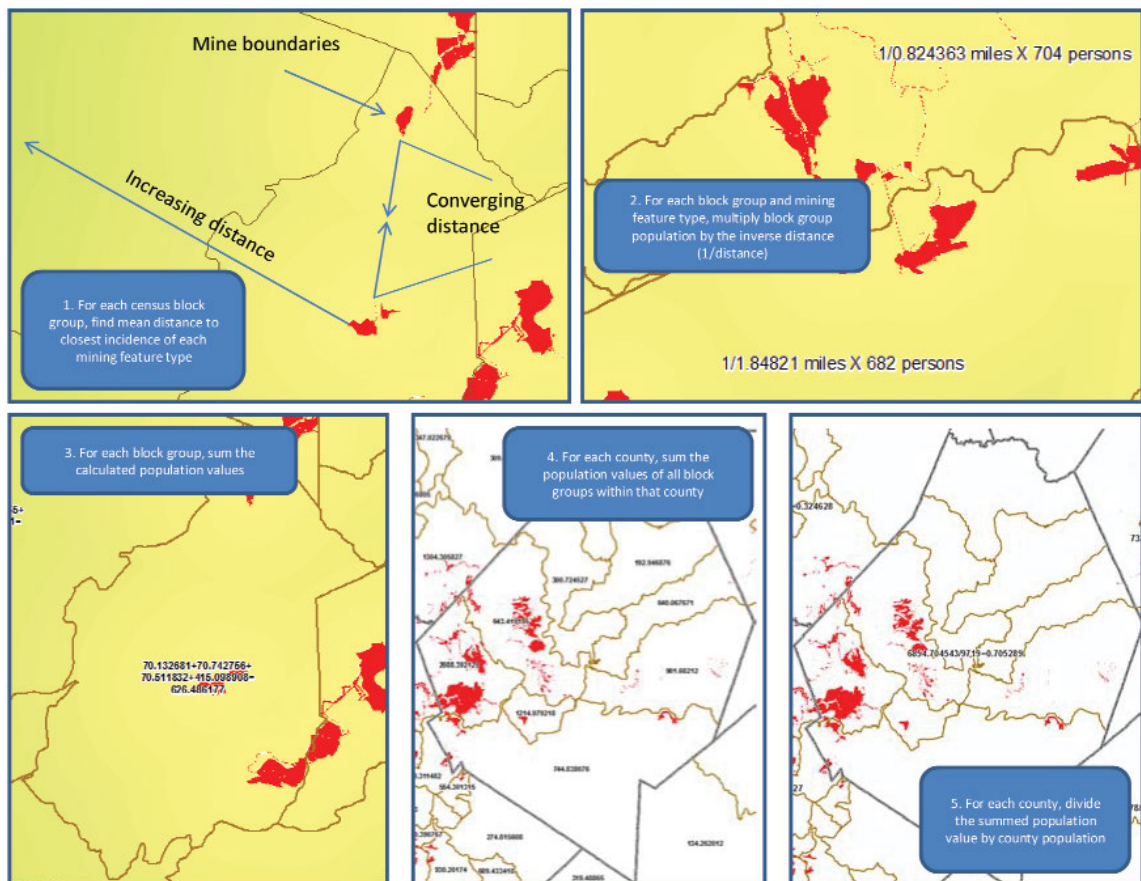


Fig. 2. Representation of construction of the distance-weighted at risk population index.

4), and divided by the total county population “ $P_c$ ”, to find the total mean per capita county-level distance-weighted mining impact score (step 5). This measure of exposure can be expressed as:

$$\frac{\sum_{i=1}^k (\sum P_k (l/d_t))}{P_c}, \text{ where}$$

$$\sum P_k (l/d_t) = P_k / d_m + P_k / d_d + P_k / d_i + P_k / d_p$$

As with previously published studies (Hendryx et al., 2007, 2008ab, 2009; Hendryx and Ahern, 2008) the “old” measure of mining exposure was constructed by creating a 3-level variable that divided counties into no mining ( $n = 24$  counties), moderate mining levels ( $n = 16$ ), or high mining levels ( $n = 15$ ), based on tons of coal mined at the county-level. The boundary between moderate and high was set at 4 million tons for the years 1986-2005, the median value dividing mining counties into equal sized groups. County-level coal production statistics were drawn from the West Virginia Geologic and Economic Survey (WVGES, 2007b) which includes statistics only back to 1986. The new and old measures of exposure are termed the distance-weighted exposure measure and the tonnage exposure measure, respectively.

## Results

### Analysis

All three global spatial autocorrelation tests (cancer, coal and the bivariate) resulted in positive spatial autocorrelation. The univariate global spatial autocorrelation test of county-level age-adjusted combined cancer mortality rates yielded: Moran’s  $I = 0.405$ ;  $E[I] = -0.011$ ; mean =  $-0.008$ ; SD =  $0.066$ , where:  $E[I]$  is the expected Moran’s  $I$  and SD is the standard deviation of Moran’s  $I$ . The univariate global spatial autocorrelation test of county-level total tonnage of coal production yielded: Moran’s  $I = 0.354$ ;  $E[I] = -0.011$ ; mean =  $-0.011$ ; SD =  $0.061$ .

The bivariate global spatial autocorrelation between total tonnage of coal production per county and county-level age-adjusted combined cancer mortality rates yielded: Moran’s  $I = 0.218$ ;  $E[I] = -0.011$ ; mean =  $-0.001$ ; SD =  $0.049$ . All three global spatial autocorrelation tests yielded a pseudo significance value of  $P < 0.001$ , which indicates that the data are not spatially random.

The LISA tests resulted in three 95% significance cluster maps (Fig. 3). The county-level, age-adjusted, combined cancer mortality rates’ 95% significant cluster map (Fig. 3a) yielded six counties (Wayne, Lincoln, Mingo, Logan, Boone and Wyoming) categorized as being high-high clusters and seven counties (Preston, Tucker, Randolph, Pocahontas, Pendleton, Grant and Hardy) classified as being low-low clusters. Two counties, Putnam (low-high) and Mineral (high-low), were found to be spatial outliers. Spatial clusters, high-high and low-low, are said to be significantly higher and lower than the global Moran’s  $I$ , while the low-high and high-low clusters are individual locations significantly different than their neighbors.

The county-level, total tonnage of coal production’s 95% significant cluster map (Fig. 3b) yielded six counties (Marshall, Mingo, Logan, Boone, Wyoming and Raleigh) as being high-high clusters and nine counties (Jefferson, Berkeley Hardy, Pendleton, Monroe, Pleasants, Ritchie, Wirt, and Gilmer) classified as low-low clusters. Two counties, Wetzel and Lincoln were found to be low-high spatial outliers. The bivariate LISA 95% significant cluster map between county-level, total tonnage of coal production and county-level, age-adjusted combined cancer mortality rates (Fig. 3c), yielded five counties (Mingo, Logan, Boone, Wyoming and Raleigh) that were classified as high-high clusters, while eight counties (Wetzel, Pleasants, Ritchie, Wirt, Gilmer, Hardy, Pendleton and Monroe) were classified as being low-low clusters. There were three low-high classified spatial outliers: Jefferson, Berkeley, and Lincoln, while Marshall was the only high-low classified spatial outlier.

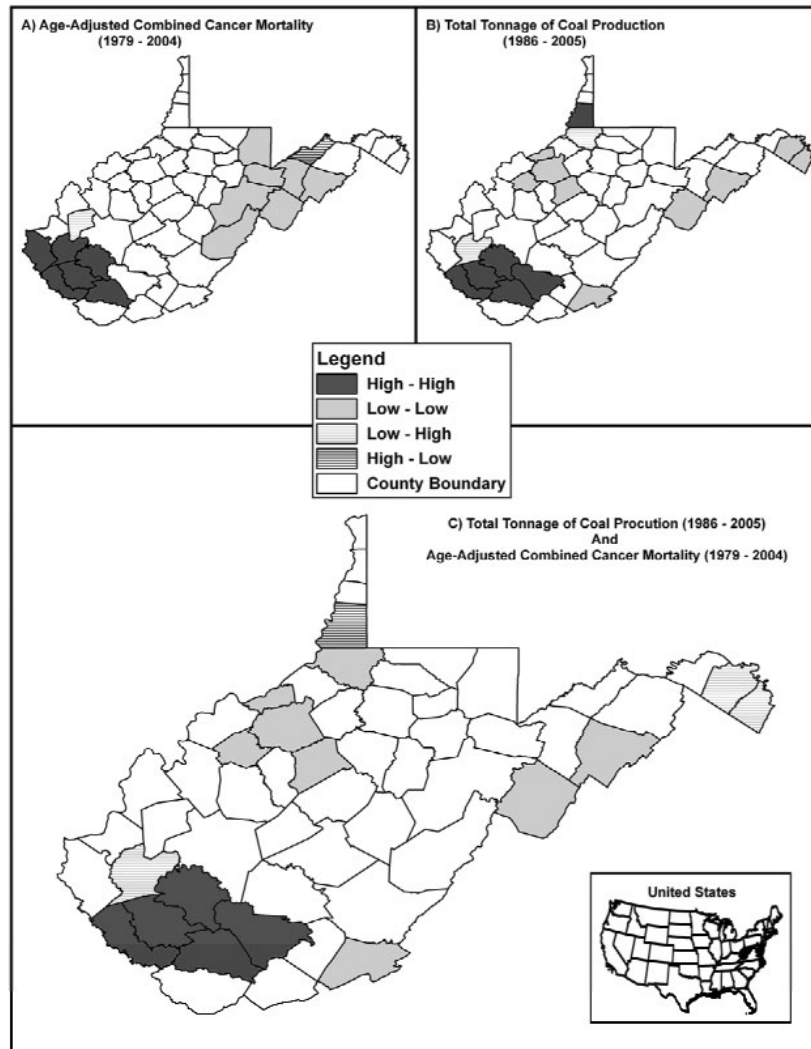


Fig. 3. Local indicators of spatial autocorrelation (LISA) cluster maps.

### *Correlation and regression analysis*

Correlations were found between age-adjusted cancer mortality rate and the alternative exposure measures in comparative models. We used Pearson correlations for the distance-weighted exposure measure and Spearman correlations for the categorical tonnage measure. Then, ordinary least squares regression models were used to compare the distance-weighted and tonnage exposure measures while accounting for covariates within con-

straints of the limited sample size, with age-adjusted cancer mortality as dependent variables. Covariates were identified using preliminary stepwise regression models setting entry into the model at  $P < 0.05$ .

Descriptive statistics on mining activity and cancer mortality are shown in Table 2. The average person lived 7 km from the nearest coal mine, 27 km from the nearest preparation plant, and 32 km from the nearest slurry impoundment or permitted underground injection site.

Table 2. Descriptive statistics: age-adjusted cancer mortality rates per 100,000 person-years and mining activity.

Cancer statistics	Mean*	Standard deviation (SD)*
Breast	14.8	2.5
Digestive	48.1	4.9
Genital	22.9	2.4
Oral	2.7	1.0
Respiratory	66.0	11.6
Urinary	9.0	1.7
Other	30.3	4.5
Total	193.6	18.5

\*County mortality rates

Mining statistics	N	Mean km distance within census block (SD)	Minimum-maximum
Injection sites	270	32.6 (31.4)	0.6 – 131.9
Slurry impoundments	105	32.1 (33.0)	0.9 – 143.4
Mining sites	4,026	7.0 (6.8)	0.08 – 35.1
Preparation plants	76	27.0 (22.6)	1.0 – 114.3

Table 3 shows that the correlations between cancer mortality and the total distance-weighted exposure were higher than the corresponding correlations between cancer mortality and the tonnage exposure measure for all cancer sites except breast

cancer. Both the old and the new measures of exposure were correlated significantly to “other” and total cancer, but the correlations reached higher levels of statistical significance for the new measure. Respiratory cancer was found to be correlated to the distance-weighted measure but not to the tonnage measure.

Selection of covariates for regression analysis is limited by the small sample size. Stepwise regression models were used to identify the most important independent variables based on a  $P < 0.05$  inclusion criterion. Two variables were thus identified: smoking rates and the weighted exposure variable. This analysis used total cancer mortality rates as the dependent variable. No other variable, including the tonnage exposure measure, race/ethnicity percentages, education, poverty, primary health care access, health insurance rates, rural-urban setting or percent female population contributed significant additional variance beyond exposure and smoking when considered in stepwise fashion. However, to test the second hypothesis, the tonnage exposure measure was carried forward with the distance-weighted exposure measure and the smoking variable into the next analyses.

When the two exposure variables were compared controlling for smoking, total cancer mortality rate remained independently associated with the dis-

Table 3. Correlations between mining activity and cancer mortality rates for distance-weighted exposure (Pearson correlation) and tonnage exposure (Spearman correlation) measures.

Cancer site	Components of distance weighted measure				Distance weighted measure	Tonnage measure
	Injection sites	Impoundments	Mines	Prep plants	Total exposure	Categorical coal mining in tons
Breast	0.28*	0.33**	0.26	0.30*	0.29*	0.29*
Digestive	0.01	0.08	0.13	-0.01	0.11	-0.06
Genital	-0.2	-0.09	0.01	-0.07	-0.03	-0.13
Oral	-0.03	-0.01	0.07	0.09	0.06	0.03
Respiratory	0.23	0.37***	0.57****	0.36***	0.53****	0.24
Urinary	0.01	0.07	0.08	0.01	0.07	-0.04
Other	0.34**	0.34**	0.43****	0.41***	0.44****	0.38***
Total	0.24	0.37***	0.55****	0.36***	0.51****	0.28*

\*  $P < 0.05$ ; \*\*  $P < 0.02$ ; \*\*\*  $P < 0.01$ ; \*\*\*\*  $P < 0.001$

Table 4. Regression results to predict age-adjusted cancer mortality from alternative exposure specifications, controlling for smoking rates.

	Distance weighted measure			Tonnage measure		
	Standardized Beta	P <	Model adjusted R <sup>2</sup> *	Standardized Beta	P <	Model adjusted R <sup>2</sup> *
Cancer site						
Breast	0.303	0.04	0.05	0.283	0.04	0.05
Respiratory	0.367	0.002	0.42	0.228	0.05	0.35
Other	0.441	0.002	0.16	0.324	0.02	0.1
Total	0.369	0.003	0.36	0.206	0.09	0.28

\* Model adjusted R<sup>2</sup> includes exposure measure and smoking rate as independent variables. F values for all models significant at P < 0.02 or greater, with the exception of both models for breast cancer, which had P < 0.10.

tance-weighted exposure measure but not the tonnage measure. Effects were significant (P < 0.05) for both exposure measures for breast, respiratory, and “other” cancer, but reached higher significance levels for respiratory and “other” cancer. These results are summarized in Table 4. Results for the remaining cancer sites were not significant with either exposure measure and are not included in the table.

## Discussion

Results of the correlation and regression analyses supported the study hypotheses. The distance-weighted, at-risk population coal mining exposure measure was significantly correlated to cancer mortality in West Virginia. For total cancer and three cancer subgroups, the exposure measure was correlated to higher mortality after controlling for smoking rates. The previous exposure measure, based on tonnage, was not related as strongly to cancer mortality. For total cancer the effect was significant only for the distance-weighted measure. The data are correlational and causal links cannot be proven, but the superior performance of the distance-weighted exposure measure is consistent with the possibility of environmental contamination from the mining industry as a causal factor in the etiology of cancer for populations residing in West Virginia.

The global Moran's *I* indicated that the variables of interest had positive spatial autocorrelation and

were spatially dependent. However, as with all correlation studies, other confounding factors could have been spatially correlated to one or both variables of interest. The LISA statistic identified these positive spatial clusters (high-high and low-low), while the spatial outliers identified areas for future research and/or investigations.

In previous published studies, based on the county measure of tonnage as the exposure variable, significant effects were found between this measure and various health outcomes including lung cancer (Hendryx et al., 2008), chronic heart, lung and kidney disease (Hendryx, 2009), and self-reported health (Hendryx and Ahern, 2008). However, these previous studies considered larger samples of counties representing the entire Appalachian region or the whole nation. In one case it was based on a large person-level sample of over 16,000 cases. In the current study, that was limited to a small sample of 55 counties, the smoking-adjusted associations did not reach as strong a statistical significance with the old categorical variable as with the new distance-weighted exposure variable as the new measure has stronger power to detect effects.

All four components of the mining industry (injection sites, preparation plants, impoundment ponds and mines) were related to one or more cancer types, although the injection sites were the least correlated and mining boundaries the most strongly correlated to cancer. This pattern is particularly

clear for respiratory and total cancer, and as respiratory cancer is the most common fatal cancer (see Table 1), it drives much of the total cancer variance. The strong association between respiratory cancer and mining boundaries, controlling for smoking, may reflect air quality problems around the mines, especially at mountaintops and other surface mining operations. Dust from coal mining is more severe at surface versus underground coal mining sites (Ghose, 2007) and surface mining as a percent of total mining has been increasing in West Virginia (WVGES, 2007b).

We recognize that the study has several limitations. Firstly, imprecision exists in the temporal relationships between exposure and cancer mortality. The development of cancer from exposure to environmental pollutants is a long-term phenomenon, and yet in this study mortality for the years 1979-2004 was related to activities of the industry as they could be constructed from available sources for approximately the same years. Cancer mortality was collapsed across these years to produce sufficient cases to examine specific types of cancer at the county-level in a relatively rural state with a small population. We assume that current mining reflects past mining, and this assumption is justified based on the long history of coal mining in the region (Hickam, 1998; Goodell, 2006) but, to the extent this not being the case, error in the exposure estimates is introduced. However, because the study compared alternative measures of exposure, each with this time limitation, the relatively stronger results for the distance-exposure measure are still relevant.

The temporal imprecision extends to estimates of population characteristics that are taken from the 2000 Census and nearby years, relative to the long aggregation of cancer mortality over the period 1979-2004. Changes in population characteristics due to migration or other dynamics might influence cancer estimates separately from mining activities. We note two population characteristics in response to this. One is that the overall population of West Virginia declined between the 1980 and 1990

Census (1.94 million to 1.79 million), then was largely stable from 1990 to 2000 (1.79 to 1.81 million.) The second is that population loss to emigration affected coal-mining counties significantly more than non-mining counties: between 1980 and 1990, the average coal mining county lost 5,233 people to migration compared to a loss of 1,175 people for non-mining counties (WVDHHR 2002). Between 1990 and 2000, the average coal mining county lost 663 people, while the average non-mining county gained 2,061 people (WVDHHR, 2002). The differential loss from mining areas could serve to make our observed mining effects more conservative than they are, because people may become exposed in mining area but develop cancer later in another area.

Secondly, although these methodologies are in line with other studies (Lin et al., 2002; Reynolds et al., 2005; Choi et al., 2006) we recognize the limitations of simple distance proximity equations (Maantay, 2002). More detailed methods, such as the development of pollution surfaces (Hoek et al., 2001; Buzzelli and Jerrett, 2003), the creation of dispersion models (English et al., 1999; Poulstrup and Hansen, 2004), or more advanced proximity analysis may yield better results. We utilized the best data available to complete this study. Many of the mentioned methods would require much more detailed data, such as particulate matter measurements or water sampling regimes, or referring to data at the person level rather than the county level such as individual cancer data. The results of this study, though limited by methodology, should be sufficient to justify more detailed field studies.

Thirdly, results of the correlation and regression analyses assumed independence between observations, when in fact the results of the spatial models demonstrated autocorrelation between adjacent counties in the dependent variable, cancer mortality rates. Models that account for spatial autocorrelation such as linear mixed models might be preferable but are constrained by the data (i.e. a sample of 55 at the single level of the county). These correlated observations may be expected to overestimate

effects. However, as noted above, this problem would affect both the tonnage measure and the distance-weighted measure, and so the relatively better performance of the distance-weighted measure is still pertinent.

Lastly, the study is also limited by the ecological design in that no direct, person-level measures of environmental exposure are available. The small sample size, 55 counties, provides limited statistical power to detect effects, and the lack of effects for some cancer types may be a consequence of this. Follow up research is needed to verify environmental impacts of coal mining on local air and water quality, and relate these impacts to population health by examining person-health exposures and health outcomes.

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## Original Contribution

# Ecological Integrity of Streams Related to Human Cancer Mortality Rates

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**Abstract:** Assessments of ecological integrity have become commonplace for biological conservation, but their role for public health analysis remains largely unexplored. We tested the prediction that the ecological integrity of streams would provide an indicator of human cancer mortality rates in West Virginia, USA. We characterized ecological integrity using an index of benthic macroinvertebrate community structure (West Virginia Stream Condition Index, SCI) and quantified human cancer mortality rates using county level data from the Centers for Disease Control and Prevention. Regression and spatial analyses revealed significant associations between ecological integrity and public health. SCI was negatively related to age adjusted total cancer mortality per 100,000 people. Respiratory, digestive, urinary, and breast cancer rates increased with ecological disintegrity, but genital and oral cancer rates did not. Smoking, poverty, and urbanization were significantly related to total cancer mortality, but did not explain the observed relationships between ecological integrity and cancer. Coal mining was significantly associated with ecological disintegrity and higher cancer mortality. Spatial analyses also revealed cancer clusters that corresponded to areas of high coal mining intensity. Our results demonstrated significant relationships between ecological integrity and human cancer mortality in West Virginia, and suggested important effects of coal mining on ecological communities and public health. Assessments of ecological integrity therefore may contribute not only to monitoring goals for aquatic life, but also may provide valuable insights for human health and safety.

**Keywords:** Ecological integrity, cancer, coal mining, streams, benthic macroinvertebrates

## INTRODUCTION

Over the last 25 years, assessments of ecological integrity have become commonplace in biological conservation, but their role in public health analysis remains largely unexplored. Nonetheless, ecological integrity assessments can

provide inferences about environmental quality that are relevant for understanding environmentally mediated human disease (Rapport, 1999; Torres and Monteiro, 2002; Sala et al., 2009). Moreover, the lack of integrated research hinders the development of holistic strategies to protect ecological and human health (Wilcox et al., 2004). In this article, we evaluated the relationships between ecological integrity and human cancer mortality in West Virginia, USA.

Karr and Dudley (1981) defined ecological integrity as an ecosystem state that “support[s] and maintain[s] a

balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.” In practice, ecologists often quantify ecological integrity by sampling biological communities and calculating metrics that indicate known environmental quality gradients (Karr and Chu, 2000). In freshwater ecosystems, ecological integrity assessments have provided insights that were not available from water chemistry assays (e.g., Yoder and Rankin, 1998), because biota are exposed to multiple physical and chemical conditions simultaneously and therefore provide an integrated measure of environmental quality.

Environmental conditions clearly affect human cancer incidence and mortality rates. Genetic factors may predispose individuals to cancer risk but are thought to be secondary to the overriding role of environmental conditions (Fearon, 1997; Perera, 1997). For example, Lichtenstein et al. (2000) evaluated cancer incidence between 44,788 pairs of twins (i.e., controlling for genetic influences) and concluded that environmental factors had the principal role in causing sporadic cancers. However, the authors noted that some types of cancers, such as prostate and colorectal cancers, showed greater heritability than other cancer types (Lichtenstein et al., 2000).

Globally, cancer is one of the leading causes of death (WHO, 2009) and accounts for over 23% of annual deaths in the United States (ACS, 2010). Communities in the Appalachian region (i.e., the mountainous region from New York to Mississippi as defined by the Appalachian Regional Commission) suffer from higher rates of cancer incidence and mortality than the rest of the nation, and rates are particularly high for lung, colorectal, and cervical cancer (Barnett et al., 2000; Huang et al., 2002; Halverson et al., 2004; Cakmak et al., 2006). The elevated cancer rates are generally thought to result from high-risk behaviors, such as smoking and physical inactivity, as well as poor access to medical care (Huang et al., 2002).

However, elevated cancer mortality rates are concentrated in coal mining regions of Appalachia (Lengerich et al., 2005; Hendryx et al., 2008). These elevated rates are partly the result of the persistent socioeconomic disadvantages that characterize coal mining areas, but even after statistical adjustment for education, poverty, smoking rates, physician supply, and other risks, some forms of cancer mortality remain elevated (Hendryx et al., 2008). Moreover, elevated rates of heart, lung, and kidney disease are associated with coal mining in Appalachia, after

controlling for other risk variables (Hendryx et al., 2007; Hendryx and Ahern, 2008; Hendryx, 2009). We reasoned that if environmental contamination from coal mining was a contributing factor for human disease, ecological integrity should be negatively related to cancer and coal mining.

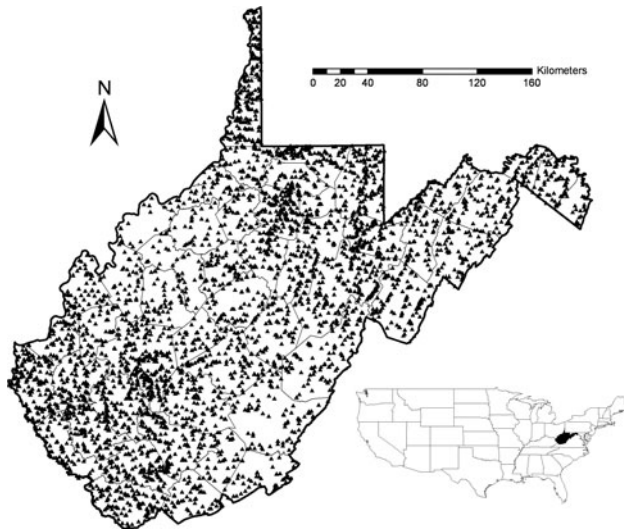
## METHODS

### Ecological Integrity

We characterized ecological integrity using the West Virginia Stream Condition Index (SCI), an index of stream benthic macroinvertebrate community structure (Gerritsen et al., 2000). Benthic macroinvertebrates are invertebrate animals that dwell on the bottom of streams (“benthic”) and are visible to the unaided eye (“macro”). These organisms exhibit important interspecific differences in their physiological and behavioral responses to pollution (Merritt and Cummins, 1996) and, therefore, are widely used in ecological integrity assessments (e.g., USEPA, 2002). Since 2002, the West Virginia Department of Environmental Protection (WVDEP) has used the SCI to assess compliance with the U.S. Clean Water Act (Huffman, 2009), and the SCI has been used to evaluate the ecological consequences of mining (Palmer et al., 2010).

The SCI is calculated from six metrics of benthic macroinvertebrate community structure, each of which has been independently tested for its sensitivity to environmental degradation: (1) the sum of taxonomic groups present; (2) the sum of individuals in the orders Ephemeroptera, Plecoptera, and Trichoptera (i.e., EPT taxa); (3) the percentage of EPT individuals in the total sample; (4) the percentage of individuals in the family Chironomidae; (5) the percentage of individuals in the top-two dominant taxa (i.e., taxonomic evenness); and (6) the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1988; Gerritsen et al., 2000). Metrics of taxonomic diversity, chironomid abundance, and EPT taxa generally decrease with increasing pollution. In contrast, taxonomic evenness typically increases with degradation (Merritt and Cummins, 1996). The HBI also increases in response to organic pollutants in streams (Hilsenhoff, 1988).

SCI calculations required several steps. First, WVDEP biologists collected a sample of stream benthic macroinvertebrates using a standardized kick-net protocol during baseflow conditions (Gerritsen et al., 2000). Second, organisms were sorted and preserved in ethanol. A random



**Figure 1.** Sampling sites (triangles) for stream condition index (SCI) data in West Virginia, USA.

subset of 200 organisms was then selected for analysis (Gerritsen et al., 2000). In the laboratory, organisms were identified to the family-level and enumerated. The six metrics (listed above) were then calculated, standardized on a 0–100 scale so that all metrics increase with increasing site quality, and averaged (Gerritsen et al., 2000). The SCI therefore ranges from 0 to 100, with high values indicating a condition of high ecological integrity and vice versa.

The SCI dataset consisted of 4718 sampling locations in West Virginia (Fig. 1) which were sampled from 1996 to 2006. We aggregated the SCI data to the county-level to permit comparisons with public health data. The minimum number of samples per county was 15 (Pleasants County) and the maximum number was 277 (Kanawha County); 50% of the counties supported at least 70 samples (Fig. 1, Appendix A). The number of samples per county was not related to mean SCI values (Pearson's  $r = 0.07$ ), thus permitting an evaluation of SCI data while avoiding potentially confounding effects of sampling effort.

## Public Health

Cancer mortality data for West Virginia were obtained from the Centers for Disease Control and Prevention database (CDC, 2008). We used county-level, age-adjusted total cancer mortality rates per 100,000 people for the combined years 1979–2005. We also evaluated cancer rates by diagnosis, including respiratory, digestive, oral, genital, urinary, breast, and “other” cancer types. We further divided genital cancer by sex to assess prostate cancer for

males, and cervical, ovarian, and uterine cancer for females. We only considered females for breast cancer rates. These groups were based on International Classification of Diseases coding criteria (ICD-9 for the years 1979–1998 and ICD-10 for the years 1999–2005) (Table 1).

## Coal Mining

We quantified coal mining intensity for each county in two ways. First, we calculated an area-adjusted measure of coal production (1000 tons/km<sup>2</sup>) with data from the West Virginia Geologic and Economic Survey (WVGES, 2009). Second, we developed a coal mining index (CMI) to characterize the associated impacts of mining (e.g., coal processing, slurry injection) as well as potential inter-county effects of mining (e.g., a mine draining into an adjacent county).

The CMI was calculated from spatial analyses of coal mining and associated activities. First, we developed state-wide maps of surface and underground coal mines, point locations of coal slurry impoundments, permitted coal slurry injection sites, and coal processing facilities. We mapped mine boundary centroids whose permit dates ranged from 1979 to 2005 ( $n = 2924$ ). We mapped slurry injection sites (i.e., coal processing waste injected underground as a means of disposal) from National Pollution Discharge Elimination System data ( $n = 270$ ). Spatial datasets were obtained from WVDEP and the U.S. Environmental Protection Agency.

Second, we mapped census block groups within the study area (US Census, 2000) and converted block groups into raster data of 30 m<sup>2</sup> cells. Third, we calculated the inverse mean distance between each grid cell and the nearest mine, impoundment, injection site, and coal preparation plant. These distances were then averaged across type of activity and block group to the county-level. CMI values were then standardized to a mean of 50 and a standard deviation of 10 (Table 1), so that increasing values indicated increasing proximities to coal mining activities. Spatial analyses were performed in ArcGIS (versions 9.2 and 9.3; ESRI, Redlands, CA).

## Statistical Analyses

We used multiple linear regression and spatial analyses to evaluate the relationships among cancer mortality, ecological integrity, and coal mining. We used linear regression techniques to model predictors of ecological

**Table 1.** Environmental and cancer summary statistics for counties in West Virginia, USA ( $N = 55$ )<sup>a</sup>

Category	Variable	Mean	SD	Minimum	maximum
Ecological integrity	Stream condition index (SCI) <sup>b</sup>	66.2	8.2	49.2	81.1
Cancer	Total	217.2	19.0	161.6	271.3
	Digestive	48.7	4.8	38.3	59.8
	Breast (female)	27.2	3.4	18.2	36.2
	Genital (female)	18.5	3.3	8.7	29.1
	Genital (male)	30.9	4.1	20.4	37.4
	Oral	5.8	1.7	1.0	9.2
	Respiratory	71.7	12.2	36.4	110.3
	Urinary	9.7	1.6	6.4	14.7
	“Other”	25.1	3.5	15.2	34.8
Coal mining	Coal mining index (CMI) <sup>c</sup>	50	10	41.5	83.7
	1000 tons/km <sup>2</sup>	48,174	87,991	0	412,689
Covariates	Smoking rate	27.8	4.0	21.1	39.0
	Urbanization <sup>d</sup>	5.6	3.4	1	12
	Poverty rate	17.2	4.9	9.0	35.5

<sup>a</sup>Cancer variables are expressed as age-adjusted mortality per 100,000 people.

<sup>b</sup>Higher SCI values indicate greater ecological integrity.

<sup>c</sup>Higher CMI values indicate greater potential influences of coal mining.

<sup>d</sup>Higher values indicate lower potential influences of urbanization.

integrity and cancer mortality, and to evaluate socioeconomic covariates. Based on prior research (Hendryx and Ahern, 2008; Hendryx et al., 2008; Hendryx 2009), we evaluated county-level data on poverty, access to health care providers, extent of urbanization, education, and smoking (US Census, 2000; USDHSS, 2006; CDC, 2007).

Poverty was expressed as the average percent of the county population below the federal poverty threshold for years 2000–2002 (USDHSS, 2006). We quantified access to health care providers as the number of active primary-care physicians per 1000 people from data in year 2000 (USDHSS, 2006). Urbanization was represented by ordinal data ranging from 1 to 12, where high values indicated low urbanization levels during 2003 (USDHSS, 2006). Education was quantified as the percent of the county population aged 25 years and older that had completed at least 4 years of college (US Census, 2000). We quantified smoking rates as the percent of adults in each county who reported being current smokers (CDC, 2007). These socioeconomic data represented some of the most recent information available for counties within the study area.

We used multiple linear regression analysis with backwards-selection to reduce the set of covariates with a  $P < 0.10$  retention criterion (Seber and Lee, 2003). Based on these analyses, we retained poverty rate, smoking rate,

and urbanization for the cancer model, and urbanization for the ecological integrity model. We then included these covariates in linear regression models of cancer mortality and ecological integrity (Huynen et al., 2004).

We used spatial analysis techniques to evaluate the geographic structure of study variables at two spatial scales. At the state-level, we calculated global Moran's  $I$  values to assess patterns of spatial autocorrelation across the study area (Moran, 1950). Positive values would indicate that nearby counties are more similar to each other than expected by chance (and negative values would indicate that nearby counties are more different from one another than expected by chance). At the county-level, we calculated local Moran's statistics to map spatial clusters (Anselin, 1995). Local Moran's methods compare observations for each county to each of its neighbors, thus producing maps of spatial clusters of low- and high-value regions (Anselin, 1995). Moran's statistics were calculated with ArcGIS toolbox applications (version 9.3; ESRI). We reasoned that if human cancer mortality increased with ecological disintegration, cancer clusters and SCI clusters would also exhibit inverse spatial associations.

We used partial Mantel tests to evaluate the possible effects of spatial autocorrelation on associations between SCI, CMI, and cancer mortality (see Hitt et al., 2003; Oden,

2005). Mantel tests are distance-based matrix correlations that use permutation procedures to establish statistical significance (Mantel, 1967). Partial Mantel tests permit the analysis of bivariate associations while controlling for the effects of additional covariates (Legendre, 2000). To develop the correlation matrices, we used Bray–Curtis distances (Bray and Curtis, 1957) of SCI, CMI, and total cancer mortality. We then expressed spatial autocorrelation as a matrix of county-wise Euclidean distances among centroids and included this matrix as a covariate in partial Mantel tests (Legendre, 2000). We assessed the significance of Mantel correlation coefficients using two-tailed *P*-values from 10,000 permutations. Distance matrices and Mantel tests were calculated using the *ecodist* package in R (Goslee and Urban, 2007).

## RESULTS

Ecological integrity (SCI) was inversely correlated to age-adjusted cancer mortality rates (Table 2). Cancer types exhibited distinct relations to ecological integrity. Digestive, breast, respiratory, and urinary cancer mortality rates were significantly correlated to SCI, whereas mortalities from female or male genital cancer, oral cancer, and “other” cancers were not (Table 2). Regression models revealed that poverty, smoking, and urbanization were

significant predictors of total cancer mortality but did not account for the observed relation between ecological integrity and cancer mortality (Table 3).

The CMI was positively correlated with total cancer mortality (Table 2) and negatively related to ecological integrity (Table 3). Coal mining was correlated with increasing respiratory cancer and “other” cancer mortalities in the study area (Table 2). The simple measure of coal mining (i.e., 1000 tons/km<sup>2</sup>) showed a similar relationship to total cancer rates and to respiratory and “other” cancer types, but the correlation coefficient magnitudes were smaller than for CMI (Table 2). We therefore used CMI for subsequent regression and spatial analyses. Urbanization was a significant predictor of SCI, but did not account for the observed relation between coal mining and ecological integrity (Table 3).

Cancer mortality exhibited significant spatial structure in the study area. Total cancer mortality rates were generally higher in the southwest portion of the state and lower in the northeast (Fig. 2), resulting in significant spatial autocorrelation among counties (Table 4). Local Moran’s statistics revealed a low-cancer cluster in the northeast portion of the state (Grant, Hardy, Pendleton, Tucker, and Randolph Counties) and a high-cancer cluster in the southwest portion of the state (Boone, Lincoln, Logan, and Mingo Counties).

Cancer types also exhibited distinct spatial structure. County-level respiratory cancer rates were highly spatially autocorrelated (Table 4), generally increasing from northeast to southwest portions of the study area (Fig. 3). As observed with the total cancer mortality, respiratory cancer exhibited a low-cancer cluster among several northeastern counties (Grant, Hardy, Pendleton, and Tucker Counties) and a high-cancer cluster among several southwestern counties (Boone, Kanawha, Lincoln, Logan, Mingo Counties) (Fig. 4). “Other” cancer rates also exhibited spatial autocorrelation among counties (Table 4), with a high-cancer cluster located in southwest (Lincoln and Logan Counties) and a low-cancer cluster in the central portion of the state (Calhoun, Gilmer, and Wirt Counties) (Fig. 4). In contrast, mortality rates for female breast cancer, digestive cancer, female or male genital cancer, oral cancer, and urinary cancer did not exhibit significant spatial structure among counties (Table 4; Fig. 3).

Ecological integrity exhibited significant spatial structure in the study area. SCI values were highest in the eastern portion of the state (Fig. 2). Significant spatial autocorrelation among counties yielded a high-integrity cluster in the

**Table 2.** Relations between cancer mortality, ecological integrity, and coal mining intensity in West Virginia, USA<sup>a</sup>

Cancer type	Ecological integrity	Coal mining	
	SCI	1000 tons/km <sup>2</sup>	CMI
Total	0.50**	0.42**	0.51**
Digestive	0.42**	NS	NS
Breast (female)	0.47**	NS	NS
Genital (female)	NS	NS	NS
Genital (male)	NS	NS	NS
Oral	NS	NS	NS
Respiratory	0.44**	0.47**	0.53**
Urinary	0.27*	NS	NS
“Other”	NS	0.40**	0.45**

<sup>a</sup>Pearson correlation coefficients are given for relations between cancer mortality rates and stream condition index (SCI) values, coal mining intensity (1000 tons/km<sup>2</sup>), and a coal mining index (CMI). Cancer was expressed as age-adjusted cancer mortality per 100,000 people. Correlation coefficients with \* or \*\* indicate *P* < 0.05 or *P* < 0.01, respectively.

**Table 3.** Linear regression models testing the relationship of ecological integrity (stream condition index, SCI) to total age adjusted cancer mortality per 100,000 people (model 1) and relationship of coal mining (coal mining index, CMI) to SCI (model 2) while controlling for covariates<sup>a</sup>

Model	Dependent variable	Independent variables	Unstandardized coefficient	SE	P
1 <sup>b</sup>	Total cancer mortality	Intercept	204.49	25.24	<0.0001
		SCI	0.61	0.27	0.028
		Poverty	1.47	0.47	0.003
		Urbanization	1.84	0.74	0.017
		Smoking	1.37	0.53	0.013
2 <sup>c</sup>	SCI	Intercept	75.41	4.98	<0.001
		CMI	0.30	0.09	0.002
		Urbanization	1.07	0.27	<0.001

<sup>a</sup>Covariates were identified by a priori analyses (see text).

<sup>b</sup> $F = 12.75$  (df = 4, 50), adjusted  $R^2 = 0.47$ ,  $P < 0.0001$ .

<sup>c</sup> $F = 13.04$  (df = 2, 52), adjusted  $R^2 = 0.31$ ,  $P < 0.0001$ .

eastern portion of the state, including Grant, Pendleton, Pocahontas, Randolph, Tucker, and Webster Counties (Table 4; Fig. 4). However, SCI exhibited no significant multi-county clusters in other portions of the state.

The coal mining index showed highest values in the southwest region of the state (Fig. 2) and exhibited significant spatial autocorrelation among counties (Table 4). High-coal clusters were detected in the northern part of the state (Monongalia County) and the southwest (Boone, Logan, McDowell, Mingo, and Wyoming Counties) (Fig. 4). One low-coal cluster was located in the central portion of the state, encompassing Ritchie and Wirt Counties (Fig. 4).

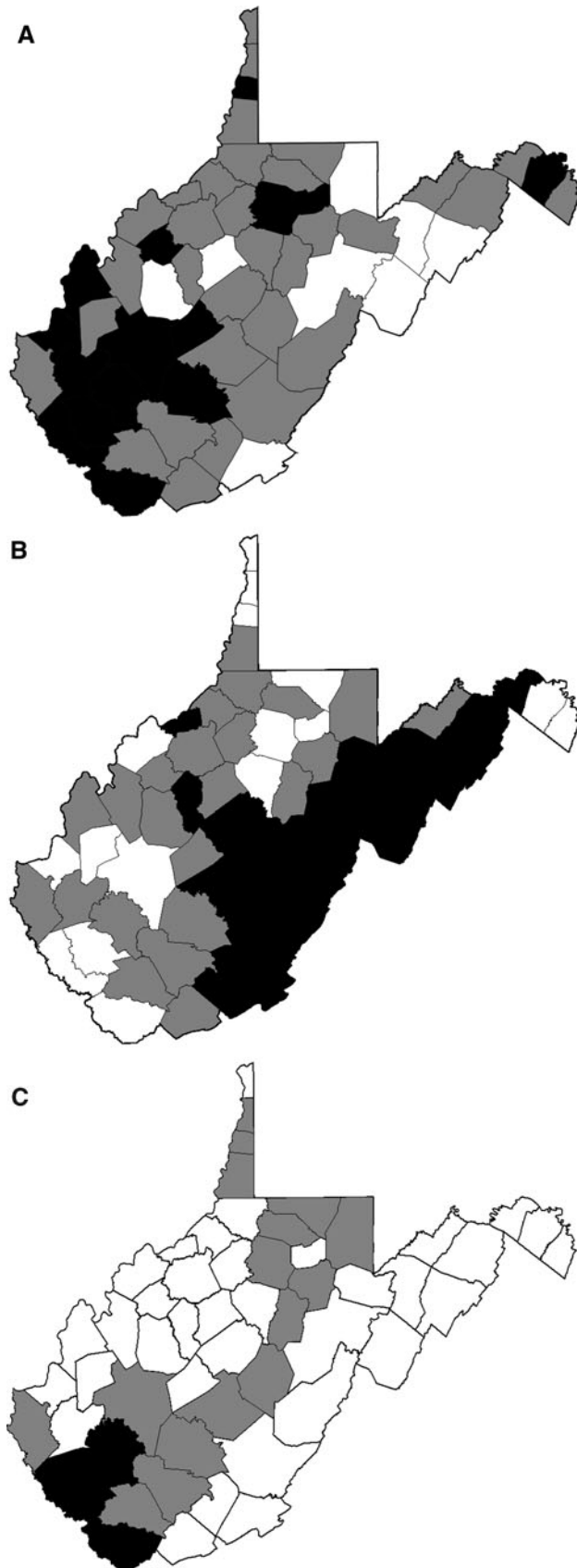
Partial Mantel tests revealed that associations between SCI, CMI, and total cancer mortality were robust to effects of spatial autocorrelation among counties (Table 5). When accounting for inter-county distances, ecological integrity (SCI) was significantly related to mining (CMI) and cancer mortality, and CMI was significantly related to total cancer mortality (Table 5). The association between ecological integrity and mining was somewhat stronger than the association between ecological integrity and cancer (i.e., Mantel  $r = 0.226$  and  $0.120$ , respectively; Table 5). Similarly, total cancer mortality revealed a somewhat stronger association with mining than ecological integrity (Mantel  $r = 0.230$  and  $0.120$ , respectively; Table 5).

## DISCUSSION

Our analysis revealed important relations among ecological integrity, human cancer mortality, and coal mining in West

Virginia (Table 2). Smoking, poverty, and urbanization were important predictors of cancer mortality, but did not account for the significant association between ecological integrity and public health (Table 3). It is well known that smoking and poverty are associated with increased risks of disease and mortality (Anderson et al., 1997; Waitzman and Smith, 1998), and our results provided additional support for this conclusion. Our study also contributed a new insight for eco-epidemiology: Stream benthic macroinvertebrate communities provided an indicator of human cancer mortality rates (Table 3), probably as a result of multiple direct and indirect exposure pathways. Although WVDEP conducts benthic macroinvertebrate sampling to assess the biological integrity of streams (Huffman, 2009), our study reveals that these assessments may also improve our understanding of human health in nearby areas. As a result, biological monitoring and assessment may provide important social benefits.

Our results demonstrated significant relationships between increasing coal mining (CMI), decreasing ecological integrity (SCI), and increasing cancer mortality (Tables 2 and 3). These results suggest, but cannot prove, a causal link between coal mining and cancer mortality. This contention is supported by prior research demonstrating that coal mining and processing may increase carcinogenic contamination of air and water in nearby areas (Griffith et al., 2004; McAuley and Kozar, 2006; Ghose, 2007; Ghose and Majee, 2007). For example, the West Virginia Geologic and Economic Survey tracks 59 impurities present in West Virginia coal, including carcinogens such as arsenic and cadmium (WVGES, 2007). Arsenic in drinking water is a



◀ **Figure 2.** Total age adjusted cancer mortality, ecological integrity, and coal mining intensity in West Virginia, USA: **a** total cancer, **b** stream condition index (SCI), **c** index of coal mining (CMI). All variables are mapped as one of three classes (Jenks' natural breaks) with low, medium, and high levels indicated as white, gray, and black polygons, respectively. Numerical breakpoints are presented in Appendix B.

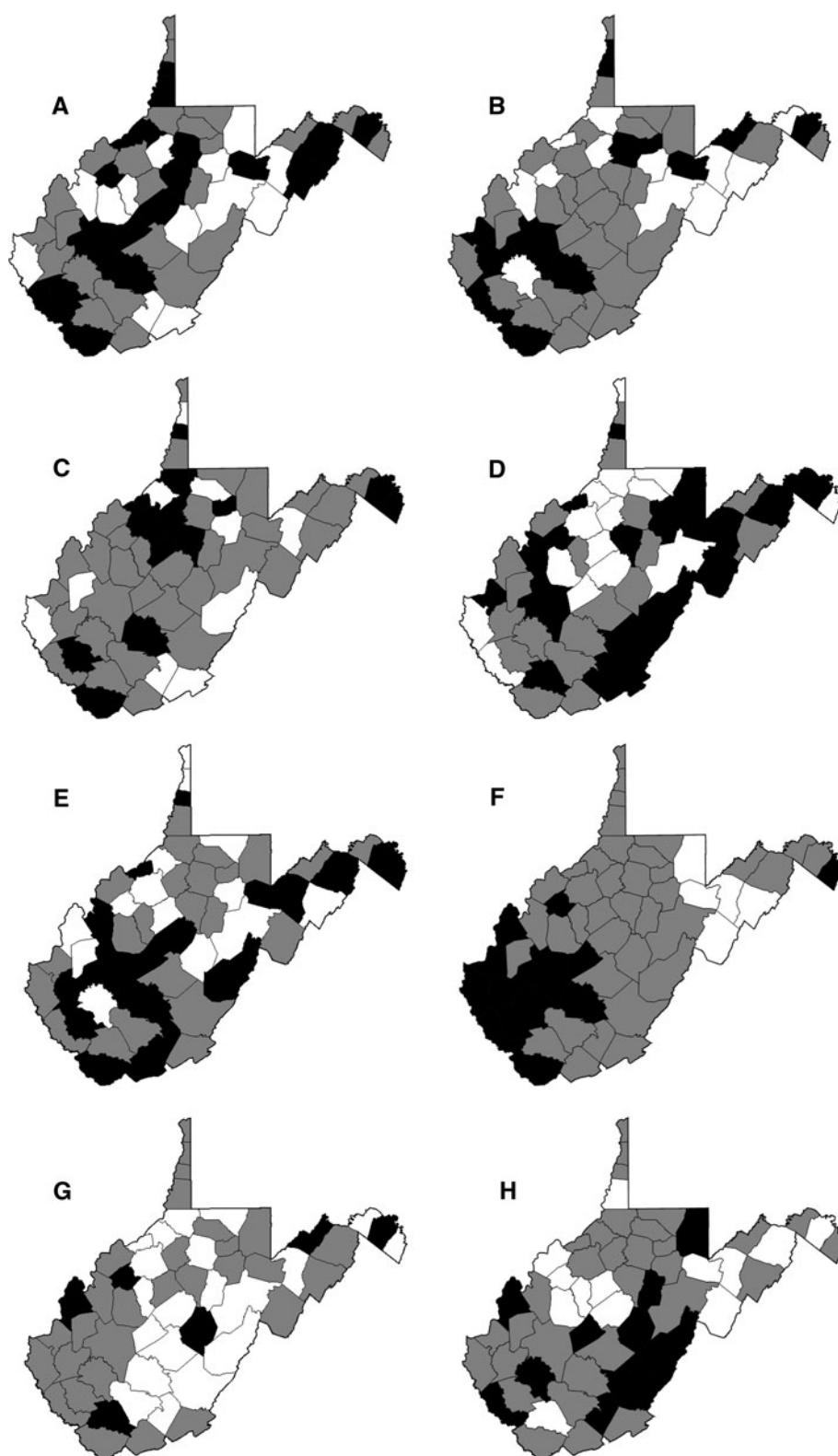
**Table 4.** Spatial cluster analysis of cancer mortality, ecological integrity (stream condition index, SCI), and coal mining (coal mining index, CMI) in West Virginia<sup>a</sup>

Category	Variable	Moran's <i>I</i>	<i>z</i> score	<i>P</i>
Cancer mortality	Total*	0.268	3.065	0.002
	Breast (female)	0.029	0.502	0.616
	Digestive	0.030	0.116	0.907
	Genital (female)	0.106	1.331	0.183
	Genital (male)	0.013	0.055	0.956
	Oral	0.064	0.477	0.633
	Respiratory*	0.456	5.091	<0.001
	Urinary	0.065	0.498	0.618
	"Other"*	0.204	2.363	0.018
Ecological integrity	SCI*	0.257	2.875	0.004
Coal mining	CMI*	0.560	6.244	<0.0001

<sup>a</sup>Cancer was expressed as age-adjusted cancer mortality per 100,000 people. Moran's *I* values were calculated using the inverse distance method and Euclidean distances. Positive Moran's *I* values indicate spatial autocorrelation among counties. Variables indicated with \* show  $P < 0.05$  and are mapped with local Moran's statistics (Fig. 4).

causal factor for lung cancer (Ferrechio et al., 2000) and skin cancer (Landrigan, 1982; Vahter et al., 2002; Jarup, 2003). Cadmium exposure is linked to many cancer types including lung, breast, and pancreatic cancer (Huff et al., 2007).

Our results are consistent with documented effects of mining on stream ecosystems in Appalachia. Several studies have demonstrated substantive differences in benthic macroinvertebrate communities between streams that flow from coal surface-mines and those that do not. For example, the extirpation of a taxonomic order of macroinvertebrates (i.e., mayflies [*Ephemeroptera*]) has been reported in mining-affected streams (Pond et al., 2008; Palmer et al., 2010; Pond, in press). Such biological changes have been attributed to changes in water quality, water quantity, and physical habitat in streams draining mining operations in Appalachia (Phillips, 2004; Hartman et al.,

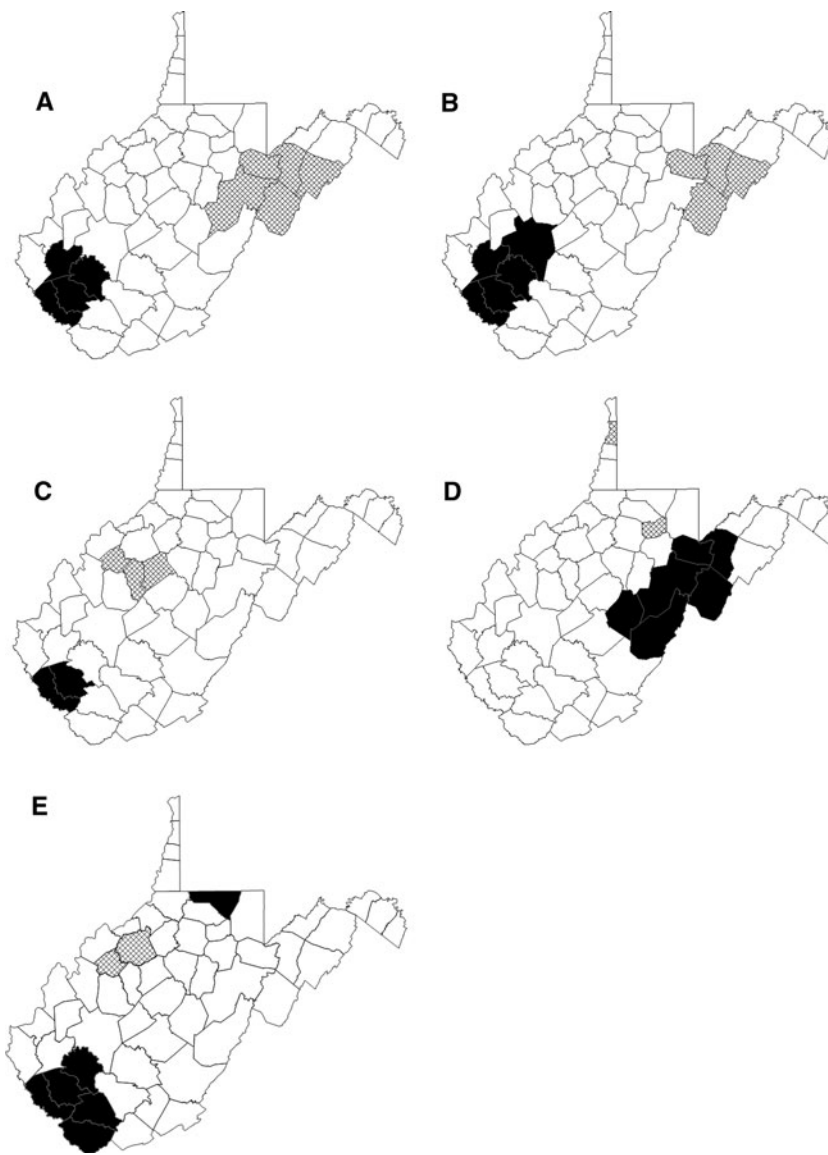


**Figure 3.** Spatial distribution of cancer types: **a** digestive; **b** breast (female), **c** genital (female), **d** genital (male), **e** oral, **f** respiratory, **g** urinary, **h** “other” cancer. All variables are mapped as one of three classes (Jenks’ natural breaks) with low, medium, and high levels indicated as white, gray, and black polygons, respectively. Numerical break points are presented in Appendix B.

2005; Negley and Eshleman, 2006; Pond et al., 2008; Palmer et al., 2010).

Some coal-mediated effects on benthic macroinvertebrates may be linked to human cancer mortality, but others

may not. For example, it is improbable that hydrological effects of coal surface-mining (Phillips, 2004; Negley and Eshleman, 2006) could influence human health, but benthic macroinvertebrate communities clearly respond to



**Figure 4.** Local Moran's  $I$  statistics for **a** total age adjusted cancer mortality, **b** respiratory cancer, **c** "other" cancer, **d** stream condition index (SCI), and **e** coal mining index (CMI). Cross hatched areas indicate values lower than the mean. Filled areas indicate areas higher than the mean. Counties with  $P < 0.10$  are shown (see Table 4).

**Table 5.** Partial Mantel Correlations of total age adjusted cancer mortality per 100,000 people, ecological integrity (stream condition index, SCI), and coal mining (coal mining index, CMI) in West Virginia<sup>a</sup>

	SCI	CMI	Total cancer mortality
SCI		0.226	0.120
CMI	0.002		0.230
Total cancer mortality	0.068	0.021	

<sup>a</sup>Upper diagonal cells indicate partial Mantel  $r$  correlation coefficients; lower diagonals indicate associated  $P$  values. Partial Mantel correlations were calculated while controlling for spatial autocorrelation (i.e., Euclidean distances among county centroids [see text]).

hydrological variation (Bunn and Arthington, 2003). In contrast, transport of dissolved metals from coal mining and processing areas may present a human exposure pathway through well-water, poorly treated municipal water, or consumption of metal-contaminated fish. Moreover, the sensitivity of mayflies to dissolved metals (Yuan and Norton, 2003), and the loss of mayflies in mining-affected streams (Palmer et al., 2010), suggest that metal contamination may be a concern for human communities in downstream areas. Our analysis does not evaluate waterborne exposure pathways directly, and we recognize that other possible exposure pathways may be of equal or greater importance for human disease (e.g., dust from mining and processing sites; Ghose and Majee, 2007).

Inferences from our study were limited by the spatial and temporal resolution of available data. The public health data in this study were limited to the county-level, and thus required averaging thousands of ecological integrity observations (Fig. 1) into 55 county averages. We also combined temporal data for SCI (1996–2006), CMI (1979–2005), and cancer mortality (1979–2005). In each case, data aggregation will tend to diminish dose–response signals because our statistical models cannot control for heterogeneity within counties and among years. Moreover, our treatment of counties as observational units (i.e., an ecologic study *sensu* Morgenstern [2008]) does not imply that individuals within counties have predictable epidemiological exposures or responses. As a result, our results should not be used to estimate per-capita health risks but instead should be interpreted as an exploratory treatment of possible cause-and-effect relationships.

New research is needed to better understand the causal relations between ecological integrity and human health. First, individual-based studies are needed to quantify per-capita cancer risks with respect to ecological integrity and socioeconomic factors. Second, analyses of macroinvertebrate genera and species are needed to understand possible mechanistic links to public health and to apply laboratory-based physiological research to field-based bioassessment survey results. For example, the SCI was calculated from family-level data, but macroinvertebrate genera have shown greater sensitivity to stressors in the Central Appalachians (Waite et al., 2004). Third, spatial analyses of human health and ecological integrity are needed across larger geographic extents to evaluate the generality of the results presented here. The recent development of a continental-scale ecological integrity dataset (Paulsen et al., 2008) provides this opportunity in North America. Our results suggest that such a continental-scale analysis would be feasible and may provide important insights.

CONCLUSION

It is intuitive that ecological integrity and human health are intrinsically linked (e.g., Rapport, 1999; Di Giulio and Benson, 2002; Tabor, 2002). However, global analyses have shown weak or statistically insignificant relations between ecological integrity and human health (Sieswerda et al., 2001; Huynen et al., 2004). In contrast, our analysis demonstrated a significant association between ecological dis-integrity and human cancer mortality in West Virginia, USA. We detected significant influences of known socio-economic risk factors (smoking, poverty, and urbanization) on cancer mortality, but these factors did not account for the observed integrity–cancer relationship. Nor could we explain our observations as a statistical effect of spatial autocorrelation within the study area. Instead, our study demonstrated that the ecological integrity of streams was significantly related to public health in nearby areas. Although the macroinvertebrate data evaluated in this study were collected to assess the quality of aquatic life, our study revealed that these assessments may also contribute an improved understanding of human health and safety.

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APPENDICES

Appendix A. West Virginia stream condition index (SCI) summary statistics by county<sup>a</sup>

County	<i>n</i>	Mean	SEM	Range	Minimum	Maximum
Barbour	51	62.6	2.4	68.7	21.2	89.9
Berkeley	80	59.4	2.1	75.6	15.7	91.3
Boone	143	63.9	1.1	78.3	19.5	97.8
Braxton	63	72.8	1.6	56.0	36.6	92.6
Brooke	52	55.2	2.2	67.2	12.1	79.3
Cabell	57	56.4	2.5	75.1	15.5	90.6
Calhoun	23	72.4	2.1	40.8	51.7	92.5

**Appendix A.** continued

County	<i>n</i>	Mean	SEM	Range	Minimum	Maximum
Clay	55	68.5	2.0	60.2	33.5	93.7
Doddridge	39	70.5	2.0	57.3	39.3	96.5
Fayette	128	64.3	1.6	77.3	17.8	95.1
Gilmer	62	62.2	1.7	65.0	27.5	92.5
Grant	81	73.4	1.8	56.7	40.3	97.0
Greenbrier	91	79.6	1.1	58.9	39.6	98.5
Hampshire	98	75.0	1.1	57.6	37.7	95.3
Hancock	40	59.1	2.7	65.0	25.4	90.4
Hardy	88	73.1	1.6	65.5	29.1	94.5
Harrison	151	49.2	1.0	60.0	13.7	73.7
Jackson	46	70.2	2.1	55.3	39.2	94.4
Jefferson	25	52.8	2.7	56.7	29.7	86.5
Kanawha	277	57.7	1.0	85.3	11.0	96.2
Lewis	65	57.6	1.8	61.8	26.4	88.3
Lincoln	100	68.9	1.6	73.3	24.1	97.4
Logan	122	57.6	1.8	79.0	15.8	94.8
Marion	56	54.7	2.3	82.3	10.6	92.9
Marshall	116	68.4	1.6	82.3	15.3	97.7
Mason	79	66.8	1.8	69.1	23.7	92.8
McDowell	120	64.4	1.6	71.4	23.2	94.5
Mercer	63	68.1	2.0	70.8	20.1	90.9
Mineral	58	69.2	2.3	86.5	9.8	96.3
Mingo	73	55.0	1.9	70.8	18.9	89.8
Monongalia	134	53.0	1.7	83.3	9.8	93.0
Monroe	52	71.8	1.8	55.2	38.2	93.4
Morgan	59	76.6	1.5	61.1	31.7	92.8
Nicholas	132	75.6	1.2	71.5	24.8	96.3
Ohio	63	54.0	2.0	70.7	12.1	82.9
Pendleton	132	74.2	1.1	56.5	39.1	95.5
Pleasants	15	71.5	3.2	45.8	51.3	97.1
Pocahontas	119	80.6	1.0	52.2	44.0	96.2
Preston	178	66.8	1.6	88.0	9.8	97.8
Putnam	59	61.1	2.4	78.4	12.5	90.9
Raleigh	156	64.1	1.3	75.2	16.5	91.7
Randolph	216	80.4	0.8	87.8	11.8	99.6
Ritchie	34	66.7	2.5	56.2	36.2	92.4
Roane	51	66.8	2.5	75.0	18.1	93.1
Summers	44	74.8	1.8	78.9	18.7	97.6
Taylor	31	56.0	2.2	43.3	33.0	76.3
Tucker	137	80.8	1.0	69.3	27.9	97.2
Tyler	43	69.3	1.9	51.7	41.1	92.8
Upshur	70	70.1	2.0	75.8	21.3	97.1
Wayne	176	63.6	1.4	82.6	13.0	95.6
Webster	79	81.1	1.1	59.2	38.3	97.4
Wetzel	70	68.0	1.6	65.0	27.0	92.0

**Appendix A.** continued

County	<i>n</i>	Mean	SEM	Range	Minimum	Maximum
Wirt	17	64.2	3.5	60.9	24.3	85.2
Wood	16	56.7	4.1	54.8	29.5	84.3
Wyoming	133	64.7	1.2	68.4	23.7	92.1

<sup>a</sup>SCI values range from 0 to 100, with increasing values corresponding to increasing levels of ecological integrity. Raw data are available from the West Virginia Department of Environmental Quality.

**Appendix B.** Numerical breakpoints mapped in Figs. 2 and 3<sup>a</sup>

Figure	Variable	Category 1	Category 2	Category 3
1A	Total cancer	161.6 200.4	200.4 223.7	223.7 271.3
1B	Stream condition index	49.2 61.1	61.1 70.5	70.5 81.1
1C	Index of coal mining	41.5 49.8	49.8 64.3	64.3 83.7
2A	Digestive cancer	38.3 45.1	45.1 50.8	50.8 59.8
2B	Breast cancer (female)	18.2 24.8	24.8 29.2	29.2 36.2
2C	Genital cancer (female)	8.7 16.0	16.0 20.0	20.0 29.1
2D	Genital cancer (male)	20.4 28.1	28.1 32.5	32.5 37.4
2E	Oral cancer	1.0 4.5	4.5 6.6	6.6 9.2
2F	Respiratory cancer	36.4 58.2	58.2 77.7	77.7 110.3
2G	Urinary cancer	6.4 9.1	9.1 11.3	11.3 14.7
2H	“Other” cancer	15.2 22.7	22.7 27.6	27.6 34.8

<sup>a</sup>Breakpoints were defined from Jenks’ natural breaks and calculated in ArcGIS (version 9.3; ESRI, Redlands, CA).

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# Residence in Coal-Mining Areas and Low-Birth-Weight Outcomes

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**Abstract** The objective of this study was to estimate the association between residence in coal mining environments and low birth weight. We conducted a cross-sectional, retrospective analysis of the association between low birth weight and mother's residence in coal mining areas in West Virginia. Birth data were obtained from the West Virginia Birthscore Dataset, 2005–2007 ( $n = 42,770$ ). Data on coal mining were from the US Department of Energy. Covariates regarding mothers' demographics, behaviors, and insurance coverage were included. We used nested logistic regression (SUDAAN Proc Multilog) to conduct the study. Mothers who were older, unmarried, less educated, smoked, did not receive prenatal care, were on Medicaid, and had recorded medical risks had a greater risk of low birth weight. After controlling for covariates, residence in coal mining areas of West Virginia posed an independent risk of low birth weight. Odds ratios for both unadjusted and adjusted findings suggest a dose-response effect. Adjusted findings show that living in areas with high levels of coal mining elevates the odds of a low-birth-weight infant by 16%, and by 14% in areas with lower mining levels, relative to counties with no coal mining. After covariate adjustment, the persistence of a mining effect on

low-birth-weight outcomes suggests an environmental effect resulting from pollution from mining activities. Air and water quality assessments have been largely missing from mining communities, but the need for them is indicated by these findings.

**Keywords** Low birth weight · Coal mining · Environmental · Coal toxicity

Residence in a coal mining area serves as an indicator of environmental contamination from the mining industry. The environment profoundly influences the genetic constitution of newborns and impacts transplacental exposure that negatively affects birth outcomes. Specifically, molecular studies have documented significant transplacental transfer of contaminants, including polycyclic aromatic hydrocarbons (PAHs) and environmental tobacco [1, 2]. In addition, the fetus may be vulnerable to pollution stored inside the mother's body [3].

Low birth weight, defined as less than 2,500 g, occurs in 5–8% of births in the United States including 2% of term births [4]. Studies show that low-birth-weight outcomes are associated with exposure to the following toxicants: lead [5, 6]; ambient air pollutants [7–12]; air pollution associated with sulfur dioxide, nitrous dioxide and/or carbon monoxide [11, 13, 14]; traffic particulates [12]; well-water nitrate level [15]; and environmental tobacco smoke [16–21]. In addition, one study shows an association between reduced birth weight and exposure to inorganic arsenic [22]. In a recent literature review, Wigle et al. [23] concluded that there is sufficient evidence that prenatal active smoking is significantly associated with low-birth-weight outcomes, and limited evidence of such an association for lead, some pesticides, environmental tobacco smoke, outdoor air

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pollution, and drinking water disinfection by-products and nitrate.

Environmental contamination can occur through a variety of locations and mediums. Accumulating evidence indicates that coal mining and processing areas are associated with significant environmental toxicity. Coal mining deposits or releases toxic chemicals into local environments, including PAHs, arsenic, mercury, lead, cadmium, selenium, nickel, and copper [24, 25]. Coal processing involves use of toxic chemicals, as well as equipment powered by diesel engines, explosives used in mining, dust from uncovered coal trucks and trains, and dust from unpaved haul roads, all of which cause environmental pollution. The materials rejected by a cleaning plant tend to be enriched in iron sulfides (e.g., pyrite and marcasite). These oxidize easily into sulfates, causing the acidification of any water that percolates through and exits from refuse piles. Acid water in turn tends to dissolve various other minerals, creating products that are potentially harmful to plants, animals, and humans.

Evidence shows that coal processing contaminates billions of gallons of water with toxic trace elements and chemical compounds used in the coal preparation process [25, 26]. Contaminated water is held in impoundment ponds, or injected underground where interface with drinking water sources may occur. Ambient particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), sulfur dioxide, and nitrous oxide are elevated in areas proximate to coal extraction, processing, and transportation [27, 28]. In a 2004 study, half of 179 samples from private wells in coal-mining areas of Appalachia had detectable arsenic [29]. Elevated levels of iron, manganese, aluminum, lead, and arsenic have been shown in ground water in mining vs. non-mining areas of Appalachia [30, 31].

Importantly, surface mining as a percentage of total mining and as absolute production figures has been increasing in the United States [32]. In West Virginia, a form of surface mining referred to as mountaintop removal mining relies on surface explosives and removal of up to 1,000 feet of rock and soil above the coal seams [33]. Levels of particulates are higher in surface mining vs. underground mining operations and result in exposure at a community, rather than miner-only, level [28, 34]. Recent evidence shows that higher mortality rates and higher rates of self-reported chronic illness among adults in coal mining areas are significantly related to age, poverty, education, smoking, and lack of health insurance; however, after controlling for these effects, the relationship between morbidity and mortality rates and residence in a coal-mining area remained significant [35–37]. These effects are population-wide for both men and women, suggesting that these effects are not limited to occupational exposure among coal miners [35–37].

Previous research on community health effects of coal mining has been limited to studies of adult health. However, given what is known about environmental toxicants and birth outcomes, a relationship between coal mining and low birth weight may also be expected. This study tests the hypothesis that pregnant mothers who live in coal mining areas will be at greater risk for low birth weight outcomes than mothers in non-mining areas after adjustment for other risk factors.

## Methods

### Data

Birth data were obtained from the West Virginia Birthscore Dataset [38], which includes records for all live births and is based primarily on the variables in the state's birth certificate record [39]. It includes variables describing the mother (e.g., age, smoking and drinking during pregnancy, number of previous pregnancies), the birth event (e.g., labor and delivery complications), and the child (e.g., birth weight, weeks gestation). Data on coal mining were taken from the Department of Energy, Energy Information Administration (EIA). Data included were the tons of coal mined in each West Virginia county for each year 2005–2007.

### Design

The study is a cross-sectional, retrospective analysis of the association between low birth weight and mother's residence in coal mining areas of the state, before and after control for covariates.

### Variables

The dependent variable of interest is birth weight. Birth weight in grams is recorded in the dataset and was converted to a dichotomous measure of low birth weight (yes/no) based on whether birth weight was less than 2,500 g. The primary independent variable of interest is residence in a county with a zero, moderate, or high level of coal mining. Counties with coal mining were divided into levels of coal tonnage: none, moderate, and high. High and moderate levels were based on a median split of total production over the years 2005 through 2007. The split occurred at 13,510,500 tons of coal.

Covariates were obtained from the Birthscore Dataset. The mother's age was converted to a categorical variable (less than 18, 18–39, 40 and above) to capture risks of low birth weight for mothers who are younger or older. Dichotomous variables measured whether the mother

smoked or drank alcohol during the pregnancy based on self-report. Marital status (married or not) was recorded, as were years of education, based again on the mother's self-report. The first month of prenatal care was coded into dichotomous variables representing early (first trimester, yes or no), late (second/third trimester, yes or no) or no prenatal care. Number of previous pregnancies was recorded, which included live births, abortions and stillbirths. Insurance coverage was grouped into Medicaid, uninsured, or private insurance. A text field on the dataset recorded the presence of a wide range of medical risks experienced by the mother, including, for example, gestational diabetes and drug addiction. For the current study, these medical risks were simply coded as the presence or absence of any recorded medical risk in the dataset.

### Validity and Reliability of Data

Regarding the validity and accuracy of the birth data, birth weight is recorded by medical personnel in grams and can thus be considered accurate. In addition, mother's age, information about the birth event (e.g., labor and delivery complications), and the child's birth weight and weeks gestation are all variables that are observed by medical personnel and recorded, and can be considered as reliable. In contrast, self-reported variables, including smoking and drinking during pregnancy, number of previous pregnancies, marital status, drug addiction, and years of education, may not be as accurate as variables recorded by medical personnel. In particular, self-reported smoking, drinking, drug-use, and previous pregnancies are likely to be understated. However, there is no reason to believe such understatement would be more severe or less severe in mining areas.

### Data Analysis

The data for this study were anonymous, and the study met the University's standards for exemption from the IRB process. The total number of live births in West Virginia for the years 2005–2007 was 45,008. Missing data on study variables reduced the sample available for analysis to 42,770 (a loss of less than 5% of cases). Descriptive analysis of all variables was first undertaken. Subsequently, inferential analyses were undertaken which employed SUDAAN Proc Multilog models to account for the complex design of individual level observations nested within county-level coal production categories. Counties with no mining served as the referent. Mothers who received early prenatal care served as the referent relative to late or no prenatal care. Medicaid coverage and no insurance coverage were included as two dummy variables with private insurance as the referent.

### Results

As shown in Table 1, for mothers residing in mining areas, there is a significant association between receiving late prenatal care and elevated risks for low birth weight outcomes. As shown in Table 2, mothers in mining areas have a significantly higher risk of low birth weight before controlling for covariates. Further, there is evidence of a dose-response effect as the odds ratio (OR) is higher in areas of higher levels of mining compared to areas of moderate mining levels.

Table 3 shows results after controlling for covariates. The risk of low birth weight is related to previously established factors as expected (Table 3). In particular, mothers

**Table 1** Summary of study variables

	No. coal mining	Moderate mining up to 13,510,500 tons	High mining 13,510,500 tons or more	Total
<i>N</i>	15,788	7,833	19,149	42,770
% LBW*	8.5	9.6	9.9	9.3
Mother's characteristics				
% age <18*	4.0	3.9	3.3	3.7
% age >39	1.3	1.4	1.5	1.4
% married*	59.3	60.2	61.5	60.5
% drink during pregnancy	0.4	0.4	0.4	0.4
% smoke during pregnancy*	26.4	31.3	27.8	27.9
% with medical risk*	26.2	20.8	29.5	26.7
% with late prenatal care*	13.5	16.3	17.8	15.9
% with no prenatal care	0.41	0.40	0.60	0.50
Mean years education**	12.9	12.6	13.0	12.9 (2.3)
Mean number of previous pregnancies (SD)	1.32	1.29	1.30	1.30 (1.4)

\* Chi square < .01

\*\* *F* test < .01

**Table 2** Summary of coal mining association with low birth weight risk, before covariate adjustment

	No. coal mining (referent)	Moderate mining	High mining
LBW odds ratio:	1.00	1.14 (1.04 1.25)	1.18 (1.10, 1.27)

Cells include odds ratio and 95% confidence interval

Model Satterthwaite adjusted chi square 19,749, *df* 3,  $P < .0001$ **Table 3** Summary of coal mining association with low birth weight risk, including covariate adjustment

	OR (95% CI)	$P <$
Independent variable		
High coal mining	1.16 (1.08, 1.25)	.0002
Moderate coal mining	1.14 (1.04, 1.25)	.0033
No coal mining (referent)		
Mother's age <18	1.03 (0.87, 1.22)	.80
Mother's age >39	1.44 (1.13, 1.85)	.003
Married	0.92 (0.86, 0.99)	.007
Drink during pregnancy	1.29 (0.84, 1.97)	.18
Smoke during pregnancy	1.88 (1.75, 2.02)	.00001
Medical risk	2.19 (2.05, 2.34)	.00001
Years education	0.96 (0.95, 0.98)	.00001
Late prenatal care	1.01 (0.93, 1.11)	.75
No prenatal care	1.79 (1.31, 2.46)	.0002
Number of previous pregnancies	0.98 (0.95, 1.00)	.22

Cells include odd ratios and 95% confidence intervals

Model Satterthwaite adjusted chi square 18,058, *df* 13,  $P < .0001$ 

who smoke, who did not receive prenatal care, who were on Medicaid, and who had recorded medical risks had a greater risk of low birth weight. Other risks include mothers who are older, unmarried, and less educated.

After controlling for these risks, areas of the state with either lower or higher levels of coal mining pose an additional independent risk (Table 3). The odds ratios for both unadjusted and adjusted findings suggest a dose response effect because they are highest for higher levels of mining compared to lower mining levels. Before adjustment, living in a high coal mining area increased the odds of a low-birth-weight infant by 19%; after adjustment, the odds were still elevated by 16%. For areas with lower mining levels, the odds of a low-birth-weight infant were increased by 13% before adjustment and 14% after adjustment.

## Discussion

This study finds a significant association between residence in coal mining areas and the risk of a low-birth-weight

outcome, after controlling for the mother's age, marital status, education, prenatal care, number of previous pregnancies, drinking and smoking behaviors, insurance coverage, and existence of medical risks. This additional risk for low-birth weight outcomes is not surprising, as proximity in coal mining counties means proximity to environmental contaminants associated with coal mining, cleaning and transport. Studies show that environmental risks in the form of air and water contamination are associated with coal mining activities, including the release of lead, arsenic, mercury, sulfur, cadmium, beryllium [40], and elevated levels of air particulates [41].

Of particular interest is the area of research examining the relationship between air particulates and fetal development. Recent studies have increasingly examined the impact of polycyclic aromatic hydrocarbons and fine particles on pregnancy outcomes, and found support for the idea that adverse pregnancy outcomes may result from maternal exposures to airborne pollution [42–46]. One recent study of the impact of PAHs on fetal development, conducted in a highly polluted area, found a significant relationship between maternal exposure to fine particles during early gestation and intrauterine growth retardation [47]. However, the study was not able to differentiate the impact of the particulates themselves, vs. the impact of co-pollutants carried by the particles. Further research is needed to differentiate impacts of air particulates vs. co-pollutants carried by particulates in coal mining areas.

Importantly, mountaintop removal mining poses unique environmental risks, including significant air particulate exposure. Mountaintop removal mining has increased in West Virginia from 19 to 42% between 1982 and 2005, and continues to increase [48]. This type of mining enables quicker access to coal with lower labor costs, but intensifies environmental degradation. The EPA estimates that between 1985 and 2001, 724 miles of Appalachian streams were permanently destroyed, and 4 million acres will ultimately be impacted by mountaintop removal mining [49]. Growth in mountain-top removal mining means that entire communities are exposed to polluting methods of mining and processing, rather than being limited primarily to those who are coal-miners.

Limitations of the study include crude coding of medical risks. Future research needs to refine categories of medical risks to understand the contribution of each of these risks on low birth weight outcomes. In addition, the level of coal mining served as an environmental proxy for air and water contamination, as no direct environmental data related to levels of air particulates or types of water contamination in each of these areas were available. An additional limitation relates to self-reported data. In particular, the percent of mothers who drank during pregnancy, for example,

may be underreported. Finally, smoking is only measured dichotomously.

As the population grows and oil prices rise, coal is increasingly being mined. Between 1996 and 2005, coal production in the United States increased by 67 million tons [50, 51]. Over 90% of national mercury and sulfur dioxide emissions for electricity generation comes from coal [52]. Follow-up studies of children born with extremely low birth weights show that they fare worse than children with normal birth weights in almost every type of assessment (neurosensory, IQ, chronic conditions, functional limitations, etc.) [53, 54], putting children born in coal mining areas at a disadvantage. This impact may continue into adulthood, as adults who were low-birth-weight infants have more chronic diseases, including hypertension, diabetes mellitus, and obesity [55]. As coal production grows, associated toxicity is increasing. It is important to recognize that environmental pollutants from coal production are controllable pollutants that need to be minimized and eliminated to ensure fetal health.

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# Underground Injection of Coal Slurry

## Water, Health, and Alternatives

A Sludge Safety Project Citizens' Report

March 19, 2009

### ABSTRACT

Underground injection of coal slurry is a serious threat to public health. Billions of gallons have been pumped underground in West Virginia, and poisonous chemicals found in this waste have been found in nearby well water and in hair samples of local citizens. As coalfield residents voice concerns about contaminated water and health problems, the DEP continues to grant underground injection permits and to excuse companies for violating water standards at injection sites. Our state can be a model of transforming public health and chose alternative means of processing coal, which have been utilized in West Virginia and are utilized across the globe.



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## What is Coal Slurry?

Before coal is sent to market it is washed in a mixture of water and chemicals to remove particles of slate, dirt, and trace elements found in the coal seam. The waste slurry is pumped underground into abandoned mines or pumped behind earthen dams into coal waste impoundments, some of which hold billions of gallons of sludge.

EPA reported in one case that slurry injected underground  
“...contains harmful contaminants which are likely to enter the public water supply, and may present an imminent and substantial endangerment to human health.”<sup>1</sup>

“... slurry’s path through the underground mine system is unpredictable... it is likely that slurry will flow to points where water is being withdrawn from the mine by domestic users.”<sup>2</sup>

## Standards for Underground Injection Control (UIC)

“In West Virginia, all ground water is considered to be existing or potential drinking water.

“In fact, if an existing mine pool is being used as a potable water source for even one person, no permit will be issued for injection into it, notwithstanding the requirement that all UIC injection must meet Federal Safe Drinking Water Standards, also called Primary Drinking Water Maximum Contaminant Levels, or MCLs, at the point of injection.

In all other cases, the mine pool is regarded as a potential drinking water source, regardless of its present quality. Therefore, the proposed injection is carefully screened to ensure that the injected material (injectate) is capable of meeting MCLs. If the applicant cannot demonstrate that the injectate can meet these standards, the permit is denied.”<sup>3</sup>

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<sup>1</sup> EPA Docket No. IV-85-UIC-101. “Determination and Consent Order in the Matter of Eastern Coal Corporations.” United States Environmental Protection Agency Region IV. August 30, 1985. Online at [http://www.sludgesafety.org/coal\\_slurry\\_inj.html](http://www.sludgesafety.org/coal_slurry_inj.html).

<sup>2</sup> EPA Docket No. IV-85-UIC-101.

<sup>3</sup> Pettigrew, Pavanne L. “History and Status of Mining Underground Injection Control at the WVDEP Division of Water and Waste Management.” Presented at the 2008 West Virginia Mine Drainage Task Force Symposium, Morgantown, WV.

## **Enforcement of Standards**

West Virginia Department of Environmental Protection (DEP) enforcement of these standards is questionable, and the DEP is unsure whether coal slurry injected underground is contaminating residential wells.<sup>4</sup> The foundation of the “careful screening” process is the reports issued by the coal companies to the DEP regarding the make-up of the coal slurry injectate. The DEP does not employ inspectors through the Underground Injection Control Office of the Division of Water and Waste Management to inspect underground injection sites into abandoned mines or to sample and analyze the slurry.

## **Preliminary Results from SCR 15<sup>5</sup>**

Senate Concurrent Resolution 15 (SCR 15) passed the 2007 West Virginia Legislature and mandated that the DEP study coal slurry contaminants and impact to ground water.

Though the DEP has missed deadlines for the report mandated by SCR 15, the DEP was willing to share their data with SSP and independent scientists as well as split samples from three of the six test sites. The slurry samples were allowed to settle and were then separated into the solid and liquid portions, which were tested separately.

The independent scientists found that both their test results and the DEP’s results showed high metal concentrations in the solid portions of the slurry. Arsenic, for example was found at 159,000 ppb, nearly 16,000 times the Primary Drinking Water Standard. The solids portion however, while injected underground, does not fall under the regulations of the Safe Drinking Water Act.

The liquid portion of the slurry, which does need to be in compliance with the Primary Drinking Water Standards, was also in violation. The heavy metals Antimony, Arsenic, Lead, Barium, Cadmium and Chromium were all found in the samples sometimes in levels over 100 times the legal limit.

The Drinking Water Standards also set secondary standards, which are not legally binding. Iron, Aluminum, Manganese, Zinc and Copper were found in levels exceeding the recommended concentrations.

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<sup>4</sup> “DEP Unsure if Coal Slurry Poisons Water Supplies: Agency to Ignore Deadline for Study.” Charleston Gazette, February 7, 2009. Online at <http://www.wvgazette.com/News/200902070209>.

<sup>5</sup> Preliminary report written by Dr. Ben Stout and Mary Ellen Cassidy both of Wheeling Jesuit University. See Appendix 1 for the full report. The WV DEP has not approved this report.

## Chemical Constituents of Coal Slurry

The harmful content in coal slurry comes from two sources: chemicals used in the processing facility and from the coal and rock itself. Because of this, the contaminants in coal slurry can vary from place to place depending on the chemical make-up of the coal being processed and the chemicals the processing company used.

### Contaminants from Coal

All the heavy metals found in coal and associated rock are found in slurry. These elements are naturally occurring, but they remain safely locked away in the buried rock and coal seams until exposed to air and water at which point they may become mobile.

Coal seams act as filters for drinking water supplies, which provides a useful analogy for coal slurry injections. Imagine taking out a used water filter, grinding up, and pumping it into the water supply. Contaminants are now able to travel through the water supply.

According to the US Geological Survey, “Coal contains toxic organic and inorganic compounds which, if mobilized into the environment, have the potential to impact human health and environmental quality.”<sup>6</sup>

Metal	Concentration (ppm)
Antimony	0.35 to 2.3
Beryllium	1.0 to 13
Cadmium	0.0027 to 0.52
Chlorine	130 to 2,300
Chromium	6.5 to 33
Cobalt	1.5 to 11
Lead	2.7 to 25
Manganese	1.9 to 43
Nickel	3.7 to 24
Selenium	1.3 to 7.3
Arsenic	0.7 to 53
Mercury	0.005 to 0.3

**Table 1. Concentration of Heavy Metals in Coal**

Source: USGS Professional Paper 1625-C Chapter F

### Mercury

Slurry samples analyzed at WVU Tech have found slurry to contain 30 ppb of mercury, which is significantly beyond the Safe Drinking Water Act standard of 2 ppb.<sup>7,8</sup> All forms of Mercury pose a level of threat to human health, though that

<sup>6</sup> Orem, William H. Coal Slurry: Geochemistry and Impacts on Human Health and Environmental Quality. (Power Point Presentation). United States Geological Survey. Viewed online March 9, 2009 at [http://www.sludgesafety.org/misc/wm\\_orem\\_powerpoint/](http://www.sludgesafety.org/misc/wm_orem_powerpoint/)

<sup>7</sup> Schoening, Richard. West Virginia University Institute of Technology, Chemistry Department. Phone correspondence with Matt Noerpel of Coal River Mountain Watch. October 30, 2008.

level can greatly vary. In the environment Mercury can easily change forms from a relatively safe form to a highly toxic one. Depending on what form it takes, mercury can have a range of effects, including neurological disorders in newborns. There is a need to know more about the composition of mercury in slurry.

## **Known Exceedances of Heavy Metals in Coal Slurry and Residential Wells**

See Appendix 2 for table.

## **Priority Hazardous Materials**

Seven of the top 10 Priority Hazardous Materials outlined by the ATSDR in 2007 are found in coal slurry. These top seven are arsenic, lead, mercury, cadmium, polycyclic aromatic hydrocarbons (PAH), benzo(a)pyrene, and benzo(b)fluoranthene. This list was developed by taking into account the material's impact on human health based on its toxicity and likelihood that it will found on sites on the National Priorities List.<sup>9</sup>

## ***Chemicals used in Processing Coal***

Chemicals include coagulants, flocculants, and surfactants, which are sometimes made up of a blend of polymers, which serve to separate the coal from the rock. When ponds are used, the water is recycled, increasing the concentration of these polymers.

According to USGS, "Toxic organic substances used to wash coal include acrylamide, PAHs, aromatic amines, chlorinated hydrocarbons, etc."<sup>10</sup>

"Even if a toxic chemical to be used in the process will not be present in the waste stream by the time it reaches the injection point under normal operating conditions, the UIC protocols forbid such substances being used at all to prevent accidents or malfunctions allowing toxic materials to reach the groundwater system."<sup>11</sup>

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<sup>8</sup> Darst, Paul. "Team Finds New Ways to Strip Mercury from Water." The State Journal. January 3, 2008. Viewed online March 9, 2009 at [www.statejournal.com/story.cfm?func=viewstory&storyid=33130](http://www.statejournal.com/story.cfm?func=viewstory&storyid=33130).

<sup>9</sup> CERCLA 2007 Priority List of Hazardous Substances. Agency for Toxic Substances and Disease Registry. Viewed March 9, 2009 online at [www.atsdr.cdc.gov/cercla/07list.html](http://www.atsdr.cdc.gov/cercla/07list.html).

<sup>10</sup> Orem, William H.

<sup>11</sup> Pettigrew, Pavanne L.

Aniline	Dibenzofuran	Hexachloro-1,3-Butadiene
Acenaphthene	Dibutyl phthalate	Hexa-Cl-1,3-
Acenaphthylene	Diethyl phthalate	Cyclopentadiene
Anthracene	Dimethyl phthalate	1,2,4-trichlorobenzene
Benidine	Dioctylphthalate	1,2-Dichlorobenzene
Benzo(a)anthracene	Fluoranthene	1,3-Dichlorobenzene
Benzo(a)pyrene	Fluorene	1,4-Dichlorobenzene
Benzo(b)fluoranthene	Hexachlorobenzene	2,4-Dinitrotoluene
Benzo(ghi)perylene	Hexachloroethane	2,6-Dinitrotoluene
Benzo(k)fluoroanthene	Indeno(1,2,3-c,d)pyrene	2-Chloronaphtalene
Benzyl alcohol	Isophorone	2-Methylnapthalene
bis(2-ethylhexyl)phthalate	N-Nitrosodi-n-propylamine	2-Nitroaniline
bis(2-chloroethoxy)-methane	N-Nitrosodiphenylamine	3-3'-Dichlorobenzidine
bis(2-chloroethyl)ether	Naphthalene	3-Nitroaniline
bis(2-chloroisopropyl)ether	Nitrobenzene	4-Bromophenyl phenyl ether
Butyl benzyl phthalate	Phenanthrene	4-Chloroaniline
Chrysene	Pyrene	4-Chhlorophenyl phenyl ether
Dibenzo(a,h)anthracene	4-Nitroaniline	
	Acrilamide	

**Table 2: Organic Compounds Found in Coal Slurry**

Source: Kentucky Division of Water. DOW-DES Analytical Data File.

## Polyacrylamide

Polyacrylamide is a commonly used chemical in the coal washing process and the subject of to lawsuits brought by sick prep plant workers. Unfortunately Polyacrylamide is not a stable molecule and is difficult and expensive to test for. It is made up of many smaller molecules called monoacrylamides. Polyacrylamide has a tendency to easily break down into monoacrylamides, which are highly toxic.<sup>12</sup>

## Health Concerns

- “At low dose coal-derived toxic organic compounds in water produce excessive cell proliferation (consistent with mutagenic effect); and at high dose, these compounds produce cell death.”<sup>13</sup>
- USGS researchers learned that liver cells exposed to coal slurry water have a higher mortality rate than liver cells exposed to clean drinking water.<sup>14</sup>

<sup>12</sup> Personal Correspondence with Dr. Michael Kostenko, M.D.

<sup>13</sup> Orem, William H.

<sup>14</sup> Bunnell, Joseph E. “Preliminary Toxicological Analysis of the Effect of Coal Slurry Impoundment Water on Human Liver Cells” United States Geological Survey. Open-File Report 2008-1143. Reston, VA. 2008.

- “...water quality studies documented contaminated well water in WV and KY communities are consistent with coal slurry toxins.”<sup>15</sup>
- At one site, “The injection operation caused waste water to be distributed over 1,020 acres of abandoned mine working and into the surrounding groundwater system.”<sup>16</sup>
- A community survey found abnormally high levels of gall bladder disease in Prenter, WV.<sup>17</sup>
- Community concerns in Rawl, Mingo County and Prenter, Boone County report similar health issues of skin rashes, cancer, gastrointestinal problems, kidney, liver and gallbladder disease.
- Results of recent well water testing in Prenter, Boone County are not yet available, though houses smell of hydrogen sulfide gas and water comes out of the tap black, brown and red.
- Residents of Prenter sent in samples of their hair for analysis and found arsenic, beryllium, aluminum, mercury, cadmium, lead, sodium, copper, iron, boron, cobalt and molybdenum.
- Using home test kits, hydrogen sulfide gas has been detected at high levels in houses in Rawl, and in Prenter as high as 30ppm. Hydrogen sulfide gas is highly corrosive. Personal safety detectors used by petrochemical workers are set to alarm at 5 to 10ppm.
- Hundreds of millions of gallons of coal slurry have been injected into abandoned mines near Rawl and Prenter.
- "I am concerned for the health of my family and our community. We know there was slurry injected underground within 3 miles of our home. With what I know about geology I see every reason how slurry could have migrated underground to our wells and drinking water supplies." Maria Lambert, Prenter Resident.
- Physicians are very rarely trained to diagnose for long term chronic toxic exposure. As you can see in the above information, many of these chemicals manifest a wide range of health effects depending on the individual and other environmental factors.<sup>18</sup>
- Two communities have filed lawsuits in West Virginia in the past two years claiming that slurry injected underground has contaminated well water and affected their health. Others have as well over the years, but, due to settlement agreements, much of that information is not accessible.
- At least two groups of prep plant workers have filed lawsuits regarding exposure to and health impacts from harmful chemicals in slurry.

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<sup>15</sup> Hendryx, Michael. “Hospitalization Patterns Associated with Appalachian Coal Mining.” *Journal of Toxicology and Environmental Health*. Taylor and Francis, 2008. ISSN: 1528-7394 print/ 1087-2620 online.

<sup>16</sup> Spadaro, Jack. Report of Investigation Larry Brown Et. Al. v. Rawl Sales and Processing Company. Mingo County, West Virginia. Contact: PO Box 442, Hamlin, WV 25523.

<sup>17</sup> Community Health Survey, Coal River Mountain Watch.

<sup>18</sup> Personal Correspondence with Dr. Michael Kostenko, MD

- Life expectancy in West Virginia counties is declining. Women especially in southern West Virginia counties are losing a decade of their lives compared to the national average.<sup>19</sup>

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<sup>19</sup> “Early Deaths: West Virginians Have Some of the Shortest Life Expectancies in the United States.” West Virginians for Affordable Health Care. Based on a 2008 Report from Harvard Researchers. Online at [www.wvahc.org](http://www.wvahc.org).

Heavy Metals***	Possible Health Effects**
Aluminum	Irritation of skin, upper respiratory tract. Damage to liver, kidneys, and lungs. Inflammation of the gastrointestinal tract. Skin or tooth discoloration.*
Arsenic	Cancer (liver, bladder, lung, kidney, and skin). Skin Damage, problems with circulatory systems, increased risk of cancer.* As has been recently linked to Alzheimer's.****
Barium	Respiratory paralysis, muscle twitching or paralysis, may effect pacemaker or the heart muscle. Increase in Blood Pressure.*
Beryllium	Lung tumors and lesions, weight loss. Intestinal lesions.*
Cadmium	Causes cancer, anemia, discoloration of teeth, & bone changes. Kidney Damage.*
Chromium	Irritation to nasal cavity and upper respiratory tract, some compounds may cause cancer. Skin problems.*
Copper	Irritation of upper respiratory tract, corneal ulcers and skin irritation, green hair. Short term: Gastrointestinal distress. Long term exposure: liver or kidney damage.*
Iron	Decreased blood pressure, bloody diarrhea or coma, vomiting, mild lethargy.
Lead	May cause cancer. Problems with joints, kidneys, and nervous system. Infertility and birth defects. Delays in physical or mental development, deficits in attention span and learning ability. Kidney problems, high blood pressure.*
Manganese	Loss of controlled movement; weakness, stiff muscles, and trembling hands, hallucinations, forgetfulness and nerve damage, Parkinson, lung embolism and bronchitis.
Selenium	Hair loss, deformed nails; rashes and redness in skin; numbness in arms or legs. Fingernail loss; numb fingers or toes, circulatory problems*
Sodium	Could interfere with blood pressure medication
Zinc	Stomach cramps, nausea, vomiting, anemia, damage to the pancreas, and decreased levels of high-density lipoprotein (HDL) cholesterol.

**Table 3: Heavy Metals Found in Coal Slurry and Potential Health Effects of Exposure**

(The health effects included in this table are potential effects that may be caused after long term exposure at certain concentrations. Little is know about low-dose, long term chronic exposure. If you have any of these symptoms, talk to your doctor. The purpose here is to share what we do know about exposure to these metals.)

\*Health information from: United States Environmental Protection Agency. Office of Water. June 2003. Poster: *National Primary Drinking Water Standards*

\*\*Health information from: Hazardous Substances Databank of the National Library of Medicine online at <http://toxnet.nlm.nih.gov/cgi-bin/sis/search>, Unless otherwise noted by (\*).

\*\*\* List of heavy metals in coal slurry: Mine Safety and Health Administration

\*\*\*\* Gharibzadeh, Shahriar. "Arsenic Exposure May be a Risk Factor for Alzheimer's Disease."

Mine Sites Known, Suspected or Proposing to Inject Underground	80
Injection Points Known, Suspected, or Proposed as of 2008	649
Injection Points Known, Suspected, or Proposed as of 2006*	478
Injection Points Known, Suspected, or Proposed as of 2004**	430
Sites Presently in the Application/Permitting Process	27
Permits (or Modifications) Issued or Reissued (2006 – 2008)	38
Injection Points Permitted (2006 – 2008)	114
Permits/Injection Points Closed/Abandoned (2006 – 2008)	5/32
Permits/Injection Points Denied (2006 – 2008)	5/34
Permits/Injection Points Invalidated (2006 – 2008)	0
Applications Voluntarily Withdrawn (2006 – 2008)	2
Applications/Injection Points presently “On Hold” (Pending Resolution of Groundwater Problems)	3/6

**Table 4. WV DEP’s Underground Injection Statistics as of 2008**

All data from WV DEP’s 2008 Biennial Report to the Legislature on Groundwater Programs and Activities unless otherwise noted: [http://www.wvdep.org/show\\_blob.cfm?ID=14320&Name=2008\\_106\\_Report.pdf](http://www.wvdep.org/show_blob.cfm?ID=14320&Name=2008_106_Report.pdf)

\* WV DEP’s 2006 Biennial Report to the Legislature on Groundwater Programs and Activities

[http://www.wvdep.org/show\\_blob.cfm?ID=10274&Name=Biennial\\_Report\\_2006full.pdf](http://www.wvdep.org/show_blob.cfm?ID=10274&Name=Biennial_Report_2006full.pdf)

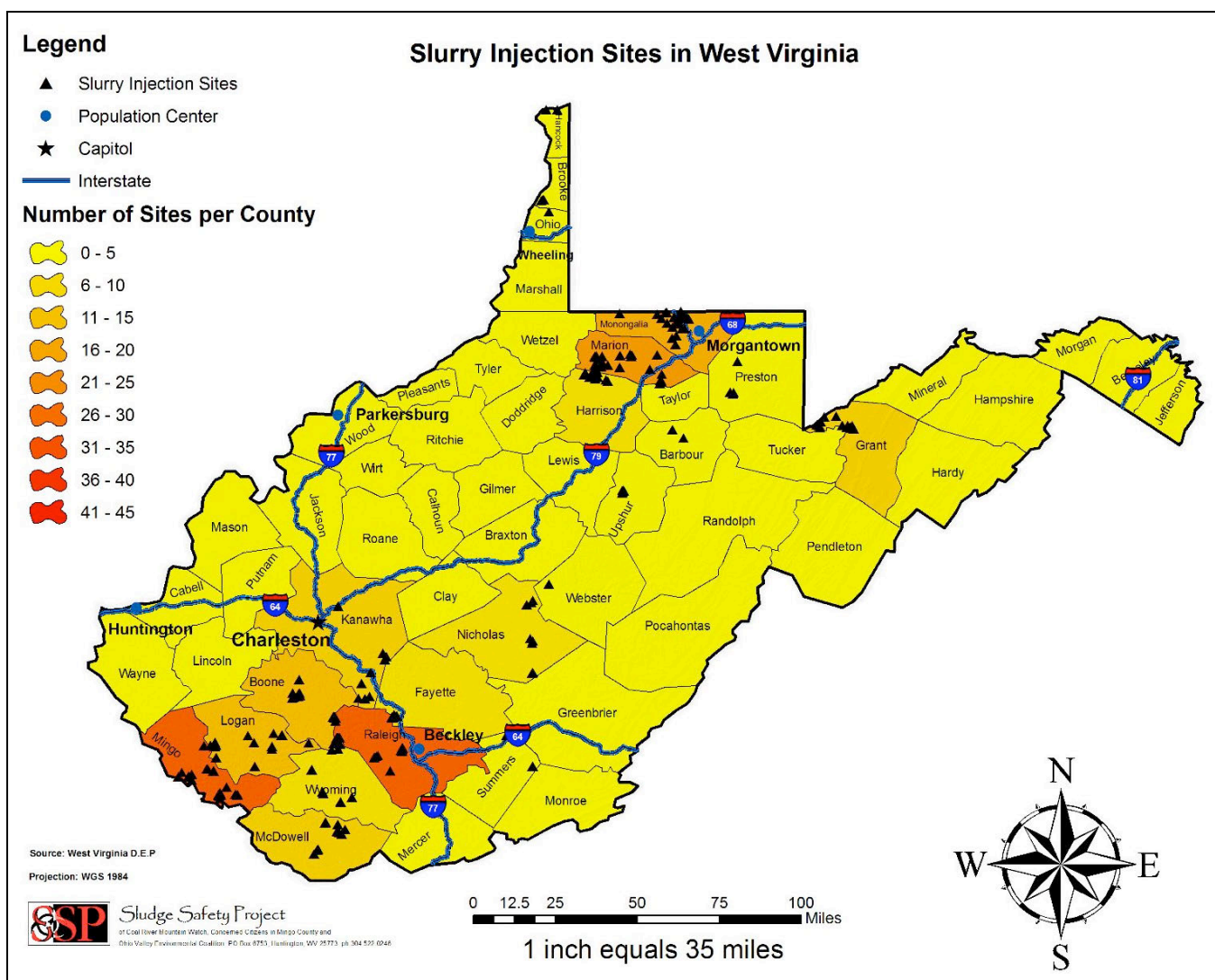
\*\* WV DEP’s 2004 Biennial Report to the Legislature on Groundwater Programs and Activities

[http://www.wvdep.org/show\\_blob.cfm?ID=10545&Name=2004\\_Biennial\\_Groundwater\\_Report.pdf](http://www.wvdep.org/show_blob.cfm?ID=10545&Name=2004_Biennial_Groundwater_Report.pdf)

	<b>Company</b>	<b>County</b>
<b>1</b>	Black Wolf	McDowell
<b>2</b>	Brooks Run Mining	Webster
<b>3</b>	Coresco, Inc.	Monongalia
<b>4</b>	Eagle Energy	Boone
<b>5</b>	Gatling Coal	Mason
<b>6</b>	ICG Beckly	Raleigh
<b>7</b>	Independence Coal Co.	Boone
<b>8</b>	Kanawha Eagle Coal, LLC	Boone & Kanawha
<b>9</b>	Power Mountain	Nicholas
<b>10</b>	Power Mountain	Nicholas
<b>11</b>	Remington, LLC	Kan/Boone
<b>12</b>	Rockspring Development	Wayne
<b>13</b>	Southern Minerals	McDowell

**Table 5. West Virginia Counties with Active Injection Permits**

Source: DEP email correspondence sent March 11, 2009



**Map 1. Injection sites documented by SSP from WVDEP Archive**

## **Alternatives to Coal Slurry**

"Dry cleaning methods should generate fewer environmental problems and require less energy than wet washing methods."

- University of Arkansas<sup>20</sup>

Many options are available to process coal without creating coal slurry including de-watering and cleaning coal without water.

### ***Latest Development in Dewatering***

Virginia Tech scientists have developed a technology that removes water from coal slurry, lowering the amount of toxic waste potentially seeping into the water table and poisoning wells. <http://www.collegiatetimes.com/stories/13009>

### ***Wet cleaning process without the slurry***

If coal is washed using a wet process, which creates the coal slurry, the slurry does not need to be disposed of immediately into impoundments or injected into abandoned mines. Dewatering processes press or filter the water from the waste. Several methods are available and fairly widely used. The most appropriate method depends on the slurry composition and planned disposal method.<sup>21</sup>

Companies in West Virginia have already utilized dry press filters. This technology relies on a closed loop of water to wash the coal. Waste slurry is pressed and dry filter cakes are created. These dry filter cakes may then be stored appropriately and more safely in lined landfills.

Marrowbone Development in Mingo County used a dry press filter well into the 1980s. Other dry press systems, and dewatering systems have been utilized in West Virginia.

Existing coal processing plants can be paired with a filter press that will dry the slurry into filter cakes that can be disposed of in a lined landfill. The cost is slightly higher (50 cents to one dollar per ton) for a conventional plant to

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<sup>20</sup> University of Arkansas, Published by US Department of Energy

<http://www.netl.doe.gov/publications/proceedings/99/99ucr/mazumder.pdf>

<sup>21</sup> Mohanty, M.K.; Wang, Z.; Huang, Z.; Hirschi, J. "Optimization of the Dewatering Performance of a Steel Belt Filter" Coal Preparation, Jan-Apr 2004, Vol. 24 Issue 1/2, p53-68, 16p; (AN 14117371)

operate with a filter press than without.<sup>22</sup> This method has been used in West Virginia.

### ***Dry Cleaning Processes***

Other methods of coal processing don't involve water at all. Such methods are popular in the Western United States where water resources are scarce and, therefore, highly valued. Dry processes vary from using air and motion to electromagnetism to separate out the coal without water and many have been around for decades. The initial capital expenditure on a dry plant is less than a wet plant and since dry processes use less energy and do away with the need for chemical input and large waste disposal areas, the operating cost is also lower.<sup>23</sup>

### **Advantages of Dry Cleaning<sup>24</sup>**

- No tailings slurry is created.
- No expensive dewatering process, such as screening, pumping, vacuum filtration or centrifuging, are necessary
- Other high cost processes such as thickeners, froth flotation and expensive reagents such as flocculants, collectors and frothers are not required
- Coal prep plants would be smaller, cheaper, require less electrical energy and would have lower operating costs
- Freight payload would be greater and subsequently, freight costs per gigajoule less, due to low levels of moisture.
- Absence of tailing ponds is ecologically attractive and rehabilitation costs of mining areas would be reduced
- Yields of "clean coal" will be relatively higher as ultrafine coal will be included in the product. Many coal preparation plants waste fine coal to tailings due to the cost of recovering it by wet methods and its disproportionate contribution to product moistures.
- Monitoring and control of effluent is not required.<sup>25</sup>

**Electrostatic separation:** Mineral matter is relatively conducting, does not retain an electric charge, and is thrown from the drum. Coal is relatively non-conducting and does retain a charge, and it adheres to the drum until being swept off with a brush. Research is being conducted to refine the process and make it more cost-effective.

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<sup>22</sup> Phone conversation with prep plant company rep.

<sup>23</sup> Donnelly, Jim. "Potential Revival of Dry Cleaning of Coal." The Australian Coal Review. October 1999.

<sup>24</sup> Donnelly, Jim.

<sup>25</sup> "The Production and Management of Dry Tailings in Coal and Uranium." A. MacG. Robertson P. Eng, Ph.D (President, Steffen Robertson and Kirsten (B.C.) Inc. and J.W. Fisher P. Eng. Draft of Paper. September 1981.

**Magnetic Separators:** The process is somewhat similar to electrostatic separation, using magnets rather than electrical charge. Research suggests that some versions of magnetic separators will reduce costs significantly—the Rare Earth Magnetic Separator (REM) can handle 4-5 tons/hour, offers 13% lower capital cost, and 50% of the operating costs compared to wet system for production of a fine coal product of equivalent energy level.<sup>26</sup>

## Sources of Information

Relatively little is known about the make up of coal slurry. Scientists, including those with the authorization and funding through the U.S. Geological Survey have been denied access to sampling and testing coal slurry impoundments.

The Martin County Coal Slurry spill in Kentucky in 2000 was about 30 times as big as the Exxon Valdez and covered 75 miles of streams. Only a handful of samples were taken.

Our understanding of coal slurry comes from this disaster in Martin County as reported by the Mine Safety and Health Administration and from a 1985 consent order from the US EPA that was based on slurry injection site about 4 miles south of Williamson, WV.<sup>27</sup>

Since the US EPA sued one coal company, Massey Energy, for thousands of Clean Water Act violations, the DEP has been allowing coal companies to settle past water pollution violations in-state. However, rather than enforcing the law and collecting overdue fines, the WVDEP is settling for much less and only reviewing violations since 2006.<sup>28 29</sup> While we have not reviewed all consent orders from these settlements, the ones we have seen have allowed us access to a fraction of the violation history of companies that have likely lead to slurry contamination.

We are awaiting the results of a SCR-15, which is a 2007 mandate from the West Virginia Legislature to the WVDEP to study coal slurry and its constituents. After 2 years, the DEP has sampled 5 underground injection sites and one impoundment and not produced a report.<sup>30</sup> While the DEP originally agreed to

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<sup>26</sup> Donnelly, Jim.

<sup>27</sup> EPA Docket No. IV-85-UIC-101. "Determination and Consent Order in the Matter of Eastern Coal Corporations." United States Environmental Protection Agency Region IV. August 30, 1985. Online at [http://www.sludgesafety.org/coal\\_slurry\\_inj.html](http://www.sludgesafety.org/coal_slurry_inj.html).

<sup>28</sup> Ward, Ken Jr. "Foundation Coal Hit with Pollution Fines." Charleston Gazette. November 22, 2008. Viewed online March 17, 2009 online at [www.wvgazette.com/news/200811210964](http://www.wvgazette.com/news/200811210964)

<sup>29</sup> "Coal Producer Pays \$20M Pollution Fine." Associated Press. Filed January 17, 2008.

<sup>30</sup> "DEP Unsure if Coal Slurry Poisons Water Supplies: Agency to Ignore Deadline for Study."

split the samples with independent scientists, they have reneged on that promise and only provided split samples from three sites in the state. However, the DEP has graciously provided us with their data, which has been interpreted by scientists at Wheeling Jesuit University.

We have worked with universities to test citizen wells and streams near coal sludge storage where we have found correlations in water supplies with contents of slurry. We have pieced together information about individual components of coal slurry, though we do not know how these chemicals interact with each other under certain conditions underground, and we have not had the resources to adequately test for many parameters that are of concern, such as organics.

In a 2002 report, the National Research Council of the National Academy of Sciences recommended further study to identify chemical constituents contained in liquid and solid fractions of slurry and to characterize the hydrogeologic conditions near coal sludge storage. The report also stressed the need for research on alternative waste disposal methods.<sup>31</sup>

## **Recommendations**

The Sludge Safety Project urges the WV 2009 Legislature to pass a moratorium on all sludge until studies can prove it is not a public health hazard.

We make the following additional recommendations:

Municipal water and, more immediately, emergency drinking water be provided to residents near coal slurry sites, including Prenter in Boone County, Jones Branch in Nicholas County, Mud River and Harts in Lincoln County, and Bridge Fork in Fayette County.

The WV Department of Health and Human Resources initiate the health portion of SCR-15 with a renewed mandate to focus research where the DEP and DHHR have received complaints of black water, bad water, and health problems near where coal slurry is stored.

Require the DHHR to submit a budget and timeline for the health portion of the SCR-15 study.

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<sup>31</sup> Committee on Coal Waste Impoundments, National Academy of Sciences. "Coal Waste Impoundments: Risks, Responses, and Alternatives." National Academy Press. Washington, DC. 2002. Online at [http://www.nap.edu/openbook.php?record\\_id=10212&page=R1](http://www.nap.edu/openbook.php?record_id=10212&page=R1)

Cease all settlements for UIC violations and require companies to pay full fines. These fines may be used to provide drinking water projects to impacted communities. One company that settled on Clean Water Act violations was required to pay \$20 Million. Full back fines totaled \$2.4 Billion. The state didn't see a cent.

Expand the coal slurry study, SCR-15 to consider the toxicity and leaching potential of coal slurry impoundments, as ground water and surface waters can be highly interconnected.

WVDEP must employ a minimum of 4 inspectors specifically for enforcement of UIC regulations in regard to coal mines.

Require best practices regarding coal processing, which would only produce dry waste.

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**Letter Health Consultation**  
**Review of Ambient Air Monitoring Data**

**Summary of Roda Air Exposures**

**Roda, VA**

**March 2010**

**Prepared by**



## **Health Consultation: A Note of Explanation**

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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David K. Paylor  
Director  
Virginia Department of Environmental Quality  
629 East Main Street  
Richmond, VA 23219

Dear Mr. Paylor:

This letter Health Consultation serves as the written Agency for Toxic Substances and Disease Registry (ATSDR) response to your May 11, 2009 letter. In that letter, the Virginia Department of Environmental Quality (VADEQ) asked ATSDR to evaluate reported levels of PM10 air pollution in the Roda, Virginia area in the context of public health questions raised about these sampling results. As we stated in our September 21, 2009 acknowledgement letter to you, ATSDR accepted your request and reviewed the information you submitted to us, including:

1. Aneja, V. 2009. Characterization of Particulate Matter (PM10) in Roda, Virginia. North Carolina State University.
2. Turner, C. 2009. Report on Monitoring Study in Roda, Virginia. Virginia Department of Environmental Quality. August 26.
3. Skelly and Loy. 2009. Ambient Dust Characterization for Roda Road. Va State Route 685, Wise County, Virginia. Prepared for Cumberland Resources Corporation. August.

ATSDR Region 3 staff members have had detailed verbal and electronic communications with VADEQ Southwest Regional Office staff members regarding this concern over the past several months. As your staff recognize, community exposures to particulate matter are complex to evaluate. The particulate matter air quality picture in the Roda area is complicated by the contributions of coal dust, road dust, and diesel truck emissions.

ATSDR concludes that exposure to particulate matter at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM10 particulate consisted of PM2.5. A limitation of the data sets available for ATSDR's review is that no PM2.5 information was collected in the sampling events. ATSDR recognizes that the North Carolina State University information does not include quality assurance/quality control processes, and that VADEQ questions the validity of the data and operating procedures used in this study.

Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms. Given the subsequent measures taken to control dust along the road and the reduction in mining activities and associated truck traffic in the community, we do not know if particulate levels presently remain a public health concern for Roda residents.

Based on ATSDR's screening of the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks. These levels are comparable to "background" levels for these metals in U.S. air.

ATSDR appreciates that VADEQ and the Virginia Department of Mines, Minerals, and Energy signed an interagency Memorandum of Agreement (MOA) in December 2009 to facilitate efficient and effective administration of applicable State and Federal environmental laws, regulations and policies for the control of fugitive dust on and immediately adjacent to active coal mining sites in the Commonwealth of Virginia.

**ATSDR recommends that federal, state, and local agencies in the area should continue to take any available measures (including effective implementation of the above mentioned MOA) to reduce particulate matter and dust affecting the residential areas along Roda Road, and in other areas with similar conditions in the state. Effective implementation of this MOA should help in addressing issues in communities with similar air quality concerns from mining/trucking activities. If the State Air Pollution Control Board finds that the MOA is not effective in addressing these air quality concerns at Roda or other similar sites, then ATSDR recommends that VADEQ conduct additional assessment efforts to further evaluate this exposure concern, such as receptor-specific and ambient monitoring for both PM<sub>2.5</sub> and PM<sub>10</sub> exposures, and consider other requirements as needed. VADEQ should consult with the appropriate agencies should the further need for this kind of additional monitoring arise. Lastly, residents in the most impacted areas should consider personal health-protective steps to limit their particulate matter and dust exposures, as described in more detail in the Health Consultation document.**

We hope this letter provides useful information to VADEQ as you continue to work on this difficult problem. If you would like to discuss the information in this letter further, please contact me at 215-814-3141 or via email at [lkw9@cdc.gov](mailto:lkw9@cdc.gov).

Sincerely,



Lora Siegmann Werner, MPH  
Senior Regional Representative  
Division of Regional Operations  
Agency for Toxic Substances and Disease Registry (ATSDR), Region 3

Cc: Dr. Tina Forrester, ATSDR Division of Regional Operations  
Dr. Paul Garbe and Dr. Fuyuen Yip, National Center For Environmental Health  
Dallas Sizemore and Crystal Bazyk, VADEQ Southwest Regional Office  
Dr. Sue Cantrell, VADOH/Lenowisco Health District Director  
Dr. Dwight Flammia, VADOH

# Summary of ATSDR Public Health Evaluation of Roda, VA Air Exposures

## ***Introduction and Background***

ATSDR's primary objective is to ensure that the residents of Roda, VA and state and local officials serving this community have the best information possible to safeguard public health. Residents living adjacent to Roda Road are concerned about health effects from particulate matter exposures in the community. Air quality in Roda is affected by coal mining operations and associated diesel truck traffic on Roda Road. Residents sought the assistance of the Southern Appalachian Mountain Stewards and the Sierra Club to evaluate the air quality in Roda. These organizations contracted with North Carolina State University to conduct an air sampling program in Roda in 2008. Based on the findings from this 2008 study, the State Air Pollution Control Board directed the Virginia Department of Environmental Quality (VADEQ) to gather additional monitoring data and develop a regional response plan. In May 2009, VADEQ wrote to ATSDR requesting assistance to obtain a better understanding of the potential health risks associated with particulate matter exposures in order to ensure the health and safety of the residents of Roda and the other Virginia communities. Further, VADEQ conducted a follow-up air monitoring program in Roda in 2009. ATSDR evaluated both the 2008 North Carolina State University and 2009 VADEQ sampling data for Roda.

## ***ATSDR's Public Health Consultation Process***

ATSDR's public health consultation process involves evaluating available environmental data, community concerns, and health outcome data (if available) for a site. The information from this health consultation activity is then used to decide what other activities are needed, such as recommendations to protect public health or health education. ATSDR identified "completed exposure pathways" for this evaluation. Exposure pathways are different ways that contaminants move in the environment and the different ways that people can come into contact with chemicals, such as breathing them in (inhalation). ATSDR identified one completed exposure pathway for the Roda, VA site: inhalation of particulates in the air by community members. This pathway was complete in the past, and is expected to be a completed pathway for the present and future.

We screened the available environmental sampling data for this site against the appropriate ATSDR health and environmental guidelines (acute, intermediate or chronic exposure durations). These health-based screening values are called comparison values or CVs. Comparison values are conservative estimates of contaminant levels at which no health effects would be expected. Although concentrations at or below a CV may be considered safe, concentrations above a CV will not necessarily be harmful.

## ***Conclusion***

ATSDR concludes that Roda residents exposed to particulate concentrations at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM<sub>10</sub> particulate consisted of PM<sub>2.5</sub>. Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms. Given the subsequent measures taken to control dust along the road, the reduction in mining activities and associated truck traffic in the community, and the limitations of the sampling information, we do not know if particulate levels presently remain a public health concern for Roda residents.

Based on the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks. Although this does not establish health risk, these levels are comparable to "background" levels for these metals in U.S. air.

### ***Basis for conclusion***

The primary basis for ATSDR's conclusion is the peak levels of particulate matter measured by North Carolina State University and VADEQ during air monitoring events in the community in 2008 and 2009. In the North Carolina State University sampling, the maximum PM10 result was  $469.7 \mu\text{g}/\text{m}^3$ , with PM10 results at this residential location exceeding the NAAQS standard of  $150 \mu\text{g}/\text{m}^3$  on 10 of 12 days. In the VADEQ sampling, the maximum PM10 result was  $160 \mu\text{g}/\text{m}^3$ , and this result was found at the same residential location as the maximum result in the North Carolina State sampling. Supporting evidence is provided via anecdotal reports from the community regarding observed dust levels outside and inside homes and health complaints consistent with exposures to particulate matter.

All particulate matter is not the same. Depending on the source, size, distribution, duration of exposure, and exposure conditions, particulate matter can irritate healthy people's eyes, nose, throat, and lungs. More serious health problems can occur in sensitive populations. Most healthy adults and children will recover quickly from short-term particulate matter exposures and will not suffer long-term consequences. Certain sensitive populations are more susceptible to particulate matter exposures, and can develop cough, phlegm, wheezing, shortness of breath, bronchitis, increased asthma attacks, and aggravation of lung or heart disease. Exposure to fine particles is of special concern, and can be associated with several serious health effects such as myocardial infarction. Some sensitive people might experience health problems after even short duration exposures (such as several hours or a day) to fine and/or ultrafine particles.

### ***Uncertainty***

In general, the 2008-2009 air monitoring information provides a snapshot in time of conditions existing in the recent past that may not be representative of current conditions. Data quality issues and concerns about non-mining related air quality influences during the sampling periods (e.g., roadwork and collection issues in 2008 and potential burning activities in 2009) contribute to the uncertainty in this evaluation. Further, an important specific data gap is the lack of sampling information for smaller particulate matter (i.e., particulate matter less than less than 2.5 micrometers in diameter (PM2.5) and ultrafine particles), and the lack of receptor-specific monitoring locations and/or personal monitoring that could define short-term exposures during high intensity mining/truck traffic periods.

### ***Next Steps***

1. Federal, state and local agencies in the area should continue to take any available measures (including effective implementation of the VADMME/VADEQ MOA) to reduce particulate matter and dust emissions affecting the residential areas along Roda Road, and in other areas with similar conditions in the state.

ATSDR understands and appreciates that VADEQ is engaged in longer term efforts with railroad and state authorities to potentially improve Roda Road. VADEQ could enhance these efforts with plans with the mining companies to continue to minimize the residential impact of the truck emissions in the area (e.g., diverting traffic to alternate roads if possible, continuing/enhancing road dust control measures involving water trucks, roadway sweepers and truck washes, instituting clean diesel controls on trucks using the road, etc). Mining activities are coming to a close in the Roda area. However, ATSDR encourages VADEQ to use the experiences gained from this site to proactively implement similar particulate matter exposure reduction activities in other communities with similar air quality concerns from mining/trucking activities.

2. If the State Air Pollution Control Board finds that the MOA is not being effective in addressing the air quality concerns at Roda or other similar sites, ATSDR recommends that VADEQ consider additional environmental assessment efforts. Options VADEQ should consider include:

- Additional environmental sampling of the fine particulate matter fraction (PM2.5 monitoring) in the air of the community. ATSDR recommends that if this sampling is conducted, that it be designed to be receptor-specific (either personal-type monitoring or ambient monitors in yards close to the road) as opposed to NAAQS-based, in order

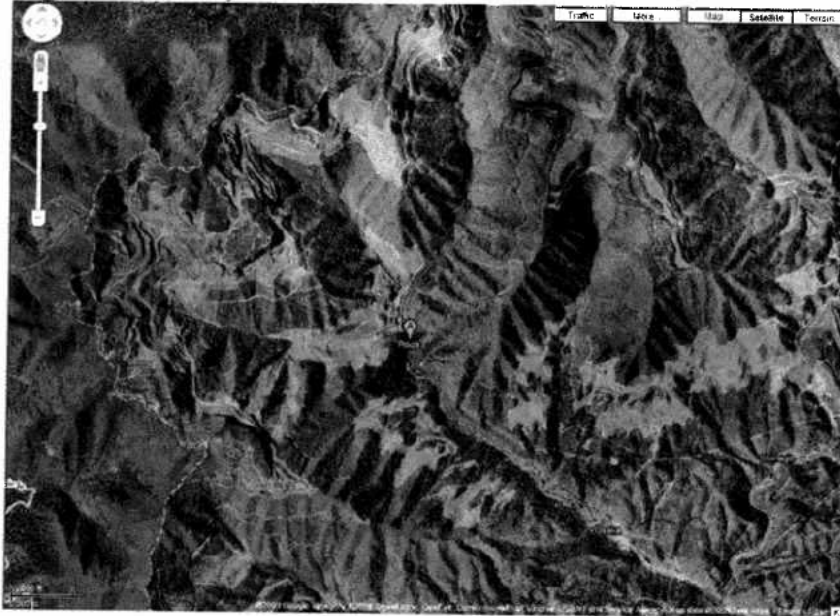
to fully address the cumulative exposures from mining and diesel exhaust in the community.

- Conducting real-time airborne dust monitoring to determine peak dust concentrations for PM10 and PM2.5.
  - Further laboratory analysis of samples collected in VADEQ's prior sampling event to generate empirical data to determine what percentage of the Roda particulate matter is coal dust.
  - Documenting with the mining company the number of trucks using Roda Road per day/week/month/year, and estimating changes in diesel emissions and subsequent community exposures based on truck volume.
3. Residents in the most impacted homes should consider personal health-protective steps to limit their particulate matter exposures, and discuss personal health concerns with a health care professional. Examples of personal health-protective steps include:
- If particle levels are high outside, keep windows and doors closed. If needed for comfort, use air conditioners or heating systems on recycle/recirculation mode, if available. Inspect and change filters often in home systems.
  - When the air quality improves (e.g., on the weekends when truck traffic is reduced), open up and air out the home.
  - Reduce indoor sources of particles, including: propane/wood/coal burning stoves and furnaces, natural gas stoves and ovens, and gas logs. Activities such as cooking, burning candles, and tobacco smoking greatly increase the particle levels in a home. Even vacuuming can stir up and greatly increase particle levels in the air.
  - Residential trash burning is a source of harmful air emissions. Residents are strongly encouraged to haul trash to approved facilities, or at a minimum to limit this activity in close proximity to homes and people.
  - Consider using a vacuum cleaner with a "high efficiency particulate arresting" or HEPA filter, if available.
  - Some air cleaners can be effective at reducing indoor particulate levels, but they must properly be matched to the size of the space to be cleaned. Keep these devices clean and the filters changed frequently.
  - Wipe floors and hard surfaces with a damp mop or cloth that will retain the dust.
  - Sensitive individuals with heart or lung disease, the elderly, and children should consider the following additional measures
    - On particularly dusty days, limit time outdoors.
    - Avoid physical exertion, indoors or outdoors, when particulate matter levels are high.
    - If you have symptoms of heart or lung disease, including shortness of breath, chest tightness, chest pain, palpitations or unusual fatigue, contact your health care provider.
    - If you have heart or lung diseases, make sure you have adequate medication on hand. If you have asthma, be sure to follow your asthma management plan.

## I. Background and Introduction

Roda is an unincorporated community located in the coalfields and mountains of Wise County, VA (Figure 1). The population of Roda, along with the neighboring unincorporated community of Osaka, consists of approximately 90 homes built within 10-20 feet from the edge of Roda Road (Route 685). Roda Road is a narrow, public road that branches off of Virginia State Route 78, and terminates after four miles at the entrance to several surface and underground coal mining operations. The mining companies haul coal by truck along Roda Road.

**Figure 1: Roda, VA Area**



Picture: 2009 Google Imagery.

In 2008, there were nine active surface mining permits with entrances at the end of Roda Road. As of February 2010, there has been a substantial reduction in the permitted operations at the end of Roda Road and there are now only three active permits on the road. Table 1 summarizes the current and expected future status of mining permit activity in the Roda area. After approximately March 1, 2010, it is expected that only a single mine (Maggard Branch Coal LLC, Big Laurel mine) in the Roda community will have an active production operation. (Personal communication, Baszyk C to Werner L 2010).

**Table 1. Summary of Mining Permit Activity in Roda, VA Area**

<i>Company</i>	<i>Permit #</i>	<i>Status</i>
A & G Coal Corporation		
	PN 1101914	Active status with mine producing minimal product, per company
	PN 1101916	Completion report; inactive per DMME
	PN 1101917	active status but not producing per DMME
Nally & Hamilton Enterprises		
	PN 1101820	Active status but not producing per DMME
	PN 1701819	in temporary cessation status per DMME
Nine Mile Spur, LLC		
	PN 1101990	Active; this is the Fairbanks mine, and they are taking coal across the mountain and not using Roda Road. This mine will close in ~1 month per the company
Maggard Branch Coal LLC		

<i>Company</i>	<i>Permit #</i>	<i>Status</i>
	PN 1201828	Guess #3 mine; active status, but closed, per company
	PN 1201890	Big Laurel mine will continue operation per company
	PN 1201945	An active mining operation in OSAKA. This area is below Roda and these trucks do not pass through Roda, per company.
	PN 1402002	Guess #4 mine; active status, but mining should be completed by the end of February per company - truck traffic not using Roda road
Meadow Branch Coal LLC		
	PN 1201972	Active status; this is a ventilation cut-out associated with Big Laurel mine. No trucking activity per company

Source: Personal communication, Baszyk C to Werner L, January 26, 2010.

As a result of the mining operations, heavy trucks travel on Roda Road. Truck traffic varies with the mining operations, but in the past residents reported that there were often at least 10 trucks every hour for up to twenty hours per day passing through the community. These trucks represent the large majority of the traffic on this road, with the remainder consisting of local residents, their families and friends, and school buses. The trucks track coal, mud, and other debris away from the mine sites and onto the road. When this mud dries it turns into dust, which is then released into the air by the passage of other vehicles. In addition, fugitive dust, including coal fines, is released directly from the trucks (North Carolina State University 2008). Further, the diesel trucks themselves emit fine particulate matter pollution from the combustion of their engines. Figure 2 is an image depicting the proximity of the truck traffic to the residences in Roda.

Figure 2: Coal Trucks Traveling Through Roda, VA



Picture: Dr. Viney Aneja. (North Carolina State University 2008)

The residents of Roda have filed complaints with the Virginia Department of Mines, Minerals, and Energy (DMME) regarding their concerns about air quality along Roda Road. Roda residents describe their health concerns as including a variety of respiratory ailments that may be linked to or exacerbated by high dust levels. The residents report that the dust levels they experience effects their quality of life and restricts the amount of time they spend outdoors. Local residents sought the assistance of the Southern Appalachian Mountain Stewards and the Sierra Club. These organizations responded with an air sampling program conducted by North Carolina State University. This sampling program was set up to

measure particulate matter 10 microns or less in size (PM10) outside the homes of two Roda residents in August 2008 (North Carolina State University 2008).

The findings from the North Carolina State University study were presented to the State Air Pollution Control Board on April 24, 2009. Based on the findings from this study, the State Air Pollution Control Board directed the Virginia Department of Environmental Quality (VADEQ)'s Office of Air Quality Monitoring to "gather monitoring data in the Roda area and develop a plan for regional response for other communities where there is a need." To meet this directive, VADEQ designed and implemented the Roda Monitoring Study. The first phase of VADEQ's study was designed to gather data to directly compare to the North Carolina State University's study results, and to evaluate PM10 from locations which meet EPA National Ambient Air Quality Standards (NAAQS) siting criteria, and this phase was completed in August 2009. The second phase was designed to ascertain PM10 levels from locations which meet EPA siting criteria and from micro-level exposures along the truck route along Stonega Road, and involved the installation of two additional PM10 monitors that would gather data through mid September 2009 (VADEQ 2009). In May 2009, VADEQ wrote to ATSDR requesting ATSDR assistance to obtain a better understanding of the potential health risks associated with the PM10 exposures in order to ensure the health and safety of the residents of Roda and the other Virginia communities. This letter was brought to the attention of ATSDR program staff members in August 2009. ATSDR began communicating with VADEQ staff members at that point, and formally acknowledged VADEQ's request for assistance in a letter dated September 2009. ATSDR formally accepted VADEQ's request for public health evaluation in December 2009.

VADEQ and the Virginia Department of Mines, Minerals, and Energy (VADMME) collaborated to sign an interagency Memorandum of Agreement (MOA) in December 2009 to facilitate efficient and effective administration of applicable State and Federal environmental laws, regulations and policies for the control of fugitive dust on and immediately adjacent to active coal mining sites in the Commonwealth of Virginia (VADMME, VADEQ 2009).

## **II. ATSDR Evaluation Process**

ATSDR's public health assessment process involves ATSDR evaluating all relevant environmental data, community concerns, and available health outcome data for a site. The information from this first activity is then used to decide what other activities are needed, such as medical testing, health education, and health promotion. This evaluation for the Roda, VA site focuses on evaluating environmental data from the site area collected in 2008 and 2009.

ATSDR identifies "exposure pathways" at the beginning of the assessment process. Exposure pathways are different ways that contaminants move in the environment and the different ways that people can come into contact with chemicals, such as breathing them in (inhalation) or accidentally drinking or eating them (ingestion). A "completed exposure pathway" exists when information shows that people have come into contact with a contaminant in soil, water, or air. Completed exposure pathways can be either in the past, the present, or could be in the future. ATSDR identified one completed exposure pathway for the Roda, VA site: inhalation of particulates in the air by community members. This pathway was complete in the past, and is also expected to be a completed pathway for the present and future. However, exposures to particulates in the community's air is expected to be less now than it was in the past, based on the reduction in mining activities and associated truck traffic in the town.

## **III. Analytical Data Summary and Evaluation**

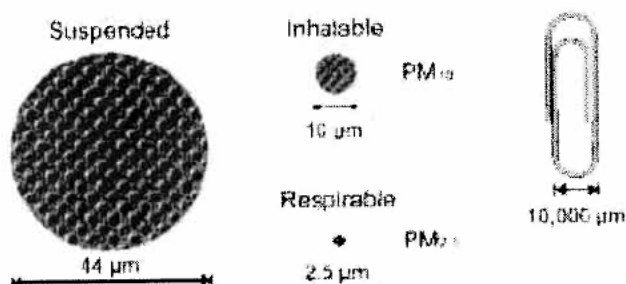
ATSDR's public health review focuses on the completed exposure pathway for this site, inhalation of particulates in the air by Roda, VA community members. Airborne particulate matter consists of many different substances suspended in air in the form of particles (solids or liquid droplets) that vary widely in size.

## Overview of Particulate Matter Sizes

The particle mix in most U.S. cities is dominated by fine particles (less than 2.5 micrometers in diameter) generated by combustion sources (such as vehicle exhaust), with smaller amounts of coarse dust (between 2.5 and 10 micrometers in diameter). Particles *smaller* than 10 micrometers in diameter include both fine and coarse dust particles. The smaller particles pose the greatest health concern because they can penetrate deeply into the lungs. Particles *larger* than 10 micrometers in diameter can cause irritation to the eyes, nose and throat in some people, but they are not likely to cause more serious problems since they typically do not get deep into the lungs. Figure 3 provides a graphic description of the different size ranges of particulate matter.

Figure 3.

### Particulate Matter Size Comparison



Picture from Air Quality Management Division, Hamilton County, OH:  
<http://www.hcdoes.org/airquality/Monitoring/PM.htm>

## Analytical Data Summary

The following sections summarize ATSDR's review of each of the three reports on air quality in the Roda area.

### 1. North Carolina State University Report:

- PM<sub>10</sub> was sampled at two locations in Roda over the course of about two weeks in early August 2008.
- The maximum PM<sub>10</sub> result was 469.7 µg/m<sup>3</sup> at the Campbell Site.
- PM<sub>10</sub> results for the Willis site exceeded the NAAQS standard of 150 µg/m<sup>3</sup> on 6 of 12 days.
- PM<sub>10</sub> results for the Campbell site exceeded the EPA National Ambient Air Quality Standard (NAAQS) of 150 µg/m<sup>3</sup> on 10 of 12 days.
- A portable meteorological station equipped with an onboard data logger was employed to measure and record site weather conditions at one of the residential monitoring locations throughout the study period.

As discussed in the summary of the VADEQ report below, the North Carolina State University's filters contained particles above the 10 micron threshold. Therefore, the North Carolina State University sampling information cannot be strictly interpreted as representing only PM<sub>10</sub> or smaller sized particles. (As stated earlier, particles larger than 10 micrometers in diameter are not likely to cause more serious health problems since they do not get down into the lungs.)

On one random day of the North Carolina State University sampling event, quartz filters were used to collect particulate samples for metals analyses. These analyses identified the presence of metals, including antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium. Not enough information is provided in this report to allow the calculation of the total particulate matter by air volume collected, and some inaccuracies were noted in the provided

information.<sup>1</sup> Therefore, ATSDR did not further evaluate the metals information collected by North Carolina State University. However, ATSDR was able to perform a screening analysis of the metals data collected by VADEQ.

## 2. VADEQ Report:

This report is the result of the State Air Control Board's order to VADEQ to "gather monitoring data in the Roda area and develop a plan for regional response for other communities where there is a need." VADEQ's study was conducted in the summer/fall of 2009 and in two phases. The first phase was to gather data to directly compare to the North Carolina State University's study results, and to evaluate PM10 from locations which meet EPA siting criteria. The second phase was to ascertain PM10 levels from locations which meet EPA siting criteria (40 CFR Part 58) and from micro-level exposures along the truck route along Stonega Road. VADEQ monitored air quality at the Campbell, Willis and Sampson sites from May 28, 2009 through August 17, 2009, and at the Wells (Stonega) and the Gibson (NAAQS compliant) sites until September 16, 2009.

- The maximum PM10 concentration was 160 µg/m<sup>3</sup>. This maximum concentration was from the Campbell site, where the North Carolina State University's study reported the highest result.
- The mean concentrations (47.7 µg/m<sup>3</sup>, 69.7 µg/m<sup>3</sup>, and 22.9 µg/m<sup>3</sup>) from each of the three locations sited in phase 1 were well below the NAAQS PM10 standard (150 µg/m<sup>3</sup>), including the Sampson site, which meets EPA siting criteria.
- Both locations which meet EPA siting criteria showed results for PM10 were below the NAAQS standard.
- The North Carolina State University's filters contained particles above the 10 micron threshold and VADEQ's filters demonstrated an effective segregation of the PM10 portion.
- Five to eight PM10 samples from five different locations were analyzed for beryllium, chromium, manganese, nickel, arsenic, cadmium and lead.

The VADEQ study concludes that based on results from the two locations which meet EPA siting criteria, "there is no regional scale PM10 issue in the area of this study." VADEQ's report states that, "overall, the PM10 concentrations at the Campbell monitoring site are generally higher than those found at the Willis site, while still averaging below the numeric standard of 150 µg/m<sup>3</sup>. The likely explanation for this difference is the proximity of the Campbell site to the coal origination points, the road configuration at the site and the existing road dust that is made airborne by the truck traffic."

ATSDR screened the VADEQ sampling results for metals that were collected from 6/6/09 through 8/5/09 against ATSDR's health based comparison values (CVs). The maximum beryllium result was below the lowest comparison value (CREG [cancer risk evaluation guide] of 0.0004 ug/m<sup>3</sup> (micrograms per cubic meter). All total chromium results (range 0.000164-0.000393 ug/m<sup>3</sup>, average 0.000278 ug/m<sup>3</sup>) exceeded the CREG of 0.00008 ug/m<sup>3</sup> for hexavalent chromium (the most conservative CV [comparison value]), but are well below the EPA reference concentration of 0.100 ug/m<sup>3</sup>. The maximum manganese result (0.03725 ug/m<sup>3</sup>) was below both the chronic EMEG (environmental media evaluation guideline) of 0.300 ug/m<sup>3</sup> and EPA's reference concentration (RfC) of 0.050 ug/m<sup>3</sup>. The maximum nickel result 0.00277 ug/m<sup>3</sup>) was below the chronic EMEG (0.090 ug/m<sup>3</sup>). The average arsenic results at each sampling location (range 0.00053-0.00089 ug/m<sup>3</sup>) exceeded the CREG (0.0002 ug/m<sup>3</sup>). The maximum cadmium result (0.00031 ug/m<sup>3</sup>) was below the lowest comparison value (CREG of 0.0006 ug/m<sup>3</sup>). No

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<sup>1</sup> Tables 1 and 2 of this report summarize the metals analytical results and comparison values used by North Carolina State University. One comparison value column header "ASTDR [as printed in the report] Standard" provides 8-hour occupational exposure standards. These are not ATSDR numbers. ATSDR does not develop 8 hour exposure standards. We do develop community screening values based on 24 hour exposures. The standard in the table for lead is based on EPA's environmental air standard averaged over a 3-month period. All the other standards are actually OSHA 8-hour permissible work exposure levels, with the wrong units (should be milligrams not micrograms) for antimony, chromium (species not noted), cobalt, manganese, mercury, nickel, and selenium. Therefore, direct comparisons to the calculated 8-hr masses are not possible without correction, except for arsenic, beryllium, and cadmium.

comparison values are available for lead dust, except the NAAQS (National Ambient Air Quality Standard) quarterly value of 0.15 ug/m<sup>3</sup>. The maximum lead result (.01249 ug/m<sup>3</sup>) was more than 10 times below the NAAQS value and the overall average (0.00201 ug/m<sup>3</sup>) was 75 times lower than the NAAQS value.

### 3. *Cumberland Resources Corporation/Skelly and Loy Report:*

This document (1) reviews the history of Roda and Roda Road, (2) evaluates the North Carolina State University study, (3) summarizes steps taken by Cumberland Resources Corporation (CRC) to manage the dust along Roda and Stonega Road, and (4) reports preliminary results of the “joint VADEQ and CRC Air Sampling Program.” Major findings in this report:

- Roda Road was constructed to support coal mining activities. The lack of space along the road limits the options for improving the road to reduce dust issues (i.e. re-entrainment). CRC spends \$900,000 per year for water trucks, roadway sweepers and truck washes to manage fugitive dust along Roda and Stonega Roads.
- This report noted the following limitations in the North Carolina State University study: (a) monitor locations did not meet NAAQS siting criteria; (2) the study was of short duration; (c) meteorological data were lacking; (d) the results were confounded by VADOT roadwork which was underway during the sampling period; and (d) the discussion of health effects was overstated (the discussion presumed that the particulate measured was in the form of PM<sub>2.5</sub> and not PM<sub>10</sub> or TSP).
- Regarding the VADEQ sampling, this report stated that there was evidence that local residents were burning refuse near the Campbell site during the sampling time period, potentially elevating the measured concentrations.
- This report concluded that the joint VADEQ and CRC study’s preliminary results suggest that ambient PM<sub>10</sub> along the Roda and Stonega Roads do not exceed EPA standards.

## ***Meteorological Information Summary***

Site-specific meteorological information provides important descriptive context for air quality investigations occurring in the same location over different time periods. The closest public meteorological station to the site collecting rainfall information is the Kingsport station (about 35 miles SE of Roda in Tennessee). At the Kingsport station, summary rainfall conditions in the summer of 2008 (when North Carolina State University sampled in Roda) were substantially drier as compared to the summer of 2009 (when VADEQ sampled in Roda). Specifically, from 5/28/08 to 8/17/08, the Kingsport station recorded 8.12 inches of rain with an average mean temperature of 73 degrees F, (with 2.99 inches of rain reported for August 2008). In contrast, for the same period in 2009, the Kingsport station recorded 13.34 inches of rain with an average mean temp of 72 degrees F (with 1.52 inches of rain reported for August 2009) (Weather Underground 2010).

Both North Carolina State and VADEQ obtained meteorological information specifically from Roda, VA during their sampling events as well. For the North Carolina State sampling, an onsite meteorological station was operated throughout the duration of the sampling event. However, rainfall information was not collected at this station (Personal communication, Aneja V. to Werner, L. 2010). VADEQ obtained their meteorological information from CRC, which began operating stations at Andover, Exeter, Roda, and Stonega in March 2009. The total rainfall measured at CRC’s Roda station from 5/28/09 to 8/17/09 was 15.81 inches (with 3.72 inches of rain reported for August 2009) (CRC Meteorological Data Summary 2010). Based on this information for the summer of 2009, more rainfall fell in Roda (15.81 inches) as compared to Kingsport (13.34 inches) over the same time period.

As noted earlier the Kingsport station is at a considerable distance from the Roda community. The terrain in this region is mountainous and complex. The CRC report (2009) notes that historical data from the National Weather Service refers to the period including the 2008 sampling as being under a drought watch, but that local weather reports indicated several days of rain. Therefore, the weather information

summarized here should only be considered approximate comparisons of the sampling environments in 2008 and 2009.

#### **IV. Public Health Implications**

ATSDR recognizes that impacts on air quality from mobile sources such as diesel trucks are regulated differently than from fixed sources such as a mining site, and that from a regulatory point of view, VADEQ has had to focus on the potential particulate (e.g., coal, soil, road dust) aspect of the air quality concern in Roda. However, from a public health (non-regulatory) perspective, ATSDR focused on the cumulative particulate matter exposure to the exposed individuals. In Roda, this cumulative exposure includes the combined particulate matter exposures from coal dust, road dust, and diesel truck emissions.

#### ***Particulate Matter Exposures***

None of the Roda air monitoring efforts to date distinguished the proportion of fine particulate matter (particulate matter of diameters 2.5 microns or less) in the air of this community.<sup>2</sup> ATSDR would expect that with the contributions from the diesel truck emissions in this community, fine particulate matter exposures would need to be considered in Roda to fully evaluate public health exposures from airborne dust.

NIOSH evaluated data from two mining operations to characterize the fugitive dust emissions from haul trucks at surface mine sites. The study consisted of unpaved and untreated roads for a limestone quarry and a coal preparation plant waste hauling operation with truck speed averages just under 16 mph. The study employed personal air samplers (37-mm cassettes) and MIE-DataRAMs. In this study, 14.5% of the dust measured was <10 µm, 3.5% of dust was <3.5 µm, and 85.5% of the measured dust was not respirable. Dust levels were highest closest to the road, and achieved background levels at a distance of 100 feet from the road. The study found that primarily wind, distance and road treatment conditions notably affected the dust concentrations at locations next to, 50 feet from, and 100 feet away from the unpaved haulage road. Airborne dust measured along the unpaved haul road showed that high concentrations of fugitive dust can be generated with these concentrations rapidly decreasing to nearly background levels within 100 feet of the road. Instantaneous respirable dust measurements illustrated that the trucks generate a real-time dust cloud that has a peak concentration with a time-related decay rate as the dust moves past the sampling locations. The respirable dust concentrations and peak levels were notably diminished as the dust cloud was transported, diluted, and diffused by the wind over the 100 feet distance from the road. Individual truck concentrations and peak levels measured next to the dry road surface test section were quite variable and dependent on wind conditions, particularly wind direction, with respect to reaching the sampling location (NIOSH 2007). In contrast, the particle size distribution from diesel truck engine emissions is strongly weighted towards the finest fractions. The particle size distribution of diesel exhaust can be described as bi-modal. The nuclei mode consists of particles 0.0075 to 0.042 µm in diameter, and the accumulation mode has particles 0.042 to 1.0 µm in diameter. Approximately 98% of the particles emitted from diesel engines are less than 10 microns in diameter, 94% less than 2.5 microns in diameter, and 92% less than 1.0 microns in diameter (NTP 2005).

Mortality as well as cardiovascular and respiratory morbidity has been associated with both short and long term exposure to PM<sub>2.5</sub> (EPA 2008). Thresholds for these health effects have not been identified. Given that there is substantial inter-individual variability in PM exposures, and in the response to a given PM exposure, it is unlikely that any standard or guideline value will lead to complete protection for every

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<sup>2</sup> Ultrafine particles are defined as those less than 0.100 micrometers (µm). Ultrafine particles are the result of combustion or friction processes or natural processes in the air or water. Animal studies have shown that ultrafine particles have a significantly greater pulmonary inflammatory potency than larger submicronic particles of the same chemical composition. These results form the basis for the ultrafine particle hypothesis, and this is an area of ongoing research particulate matter and health effects research. Ultrafine particles are not routinely monitored for in environmental sampling investigations. This hypothesis highlights the concern about the smallest sized particles.

individual against all possible adverse health effects from PM<sub>2.5</sub> exposures (WHO 2006). Several significant health studies have investigated potential health effects resulting from long-term exposure to particulate matter. The historical mean PM<sub>2.5</sub> concentration was 18 µg/m<sup>3</sup> (range 11.0 - 29.6 µg/m<sup>3</sup>) in the Six-Cities Study and 20 µg/m<sup>3</sup> (range 9.0 – 33.5 µg/m<sup>3</sup>) in the American Cancer Society (ACS) study (Dockery et al. 1993; Pope et al. 1995, 2002; HEI 2000; Jerrett 2005). Thresholds are not apparent in these studies, although the precise periods and patterns of relevant exposure could not be ascertained. In the ACS study, statistical uncertainty in the risk estimates becomes apparent at concentrations of about 13 µg/m<sup>3</sup>, below which the confidence bounds significantly widen due to the variability in the exposure concentrations. According to the results of the Dockery et al. (1993) study, the risks are similar in the cities with the lowest long-term PM<sub>2.5</sub> concentrations (i.e., 11 and 12.5 µg/m<sup>3</sup>). Increases in risk are apparent in the city with the next-lowest long-term PM<sub>2.5</sub> average concentration (i.e., 14.9 µg/m<sup>3</sup>), indicating that health effects can be expected when annual mean concentrations are in the range of 11-15 µg/m<sup>3</sup> (WHO 2006).

Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms (EPA 2008).

- Levels of pollutants that might not affect healthy people might cause breathing difficulties for people with asthma or other chronic lung diseases, especially children. Individuals with emphysema and chronic bronchitis may also experience a worsening of their conditions because of exposure to dust and smoke. Studies have linked particulate matter pollution to increased risk of hospitalizations for respiratory disease, asthma attacks, and respiratory mortality.
- People with heart disease might also experience symptoms such as shortness of breath or chest tightness. Studies have linked particulate pollution to increased risk of hospitalizations for cardiovascular disease, heart attacks, and cardiovascular mortality.
- The elderly are more likely to have pre-existing lung and heart diseases, and therefore are more susceptible to health effects from exposure to particle pollution.
- Children, even those without pre-existing illness or chronic conditions, are susceptible to air pollution because their lungs are still developing, and they are often engaged in vigorous outdoor activities, making them more sensitive to pollution than healthy adults. Studies have shown that in children, particulate pollution is associated with increased episodes of coughing and difficulty breathing, and decreased lung function.
- People who smoke, especially those who have smoked for many years, generally have reduced lung function and may be affected by dust and smoke exposure. Smokers are also less likely to recognize and report symptoms from exposure to irritant chemicals than nonsmokers.

ATSDR recognizes that the NAAQS regulatory framework is robust for addressing area-wide air quality concerns. However, the NAAQS framework is not as well suited to define localized air quality concerns that are being compounded by diesel traffic emissions (in fact, the NAAQS siting criteria are designed to minimize the impact of traffic emissions by siting NAAQS-compliant monitors sufficiently far away from roads). Therefore, even though ATSDR agrees that there may not be ambient PM<sub>10</sub> levels exceeding regulatory standards in the Roda area, the possibility remains from the available information that PM<sub>2.5</sub> exposures in the homes closest to the impacted roads exceed levels of health concern on an episodic basis.

## ***Metals Exposures***

ATSDR was unable to evaluate the North Carolina State University sampling results for metals, but we were able to screen the VADEQ sampling results for metals. In the VADEQ data, only chromium and arsenic exceed their respective cancer risk evaluation guidelines, or CREGs. All other metals (beryllium,

manganese, nickel, cadmium and lead) are below respective CVs. ATSDR evaluated the information for arsenic and chromium further in this subsection.

- **Arsenic.** All of the measured concentrations of arsenic in the VADEQ sampling event are lower than health-based comparison values for health effects other than cancer, suggesting that exposures to the measured concentration would not be expected to cause non-cancer health effects. ATSDR evaluated the potential for carcinogenic effects because inorganic arsenic is a known human carcinogen.

The maximum level of arsenic (0.00155 ug/m<sup>3</sup>) measured in total suspended particulates (TSP) in Roda corresponds to a slight (6.5 in 1,000,000) increase in the estimated risk for developing cancer following a lifetime of exposure. Although this does not establish health risk, the measured arsenic concentrations near Roda are consistent with “background” levels observed in urban and suburban locations throughout the United States. For instance, a recent review of arsenic monitoring data collected between 2003 and 2005 and reported to EPA found that 59% of monitoring locations had arsenic concentrations greater than the 1 in 1,000,000 estimated cancer risk level (McCarthy et al., 2009). Other reviews of ambient monitoring data suggest that the arsenic concentrations measured near Roda are consistent with levels routinely observed in various setting nationwide (ATSDR 2007).

- **Chromium.** All of the concentrations of total chromium near Roda measured by VADEQ are lower than health-based comparison values for health effects other than cancer, suggesting that exposures to the measured concentration would not be expected to cause such health effects. ATSDR evaluated the potential for carcinogenic effects because hexavalent chromium is a known human carcinogen.

A complicating factor is the fact that chromium found in ambient air exists in many forms that have differing toxicities. The most common forms found in ambient air are trivalent chromium and hexavalent chromium. Of these two, only hexavalent chromium is a known human carcinogen. However, most commonly-used environmental sampling and analytical methods measure ambient air concentrations of total chromium, without specifying the relative amounts of the hexavalent and trivalent forms. As a first approximation, ATSDR assumed that one-sixth of the total chromium is in the hexavalent form—an assumption frequently used and suggested in an EPA risk assessment publication (EPA 2009). Under this assumption, the estimated increased cancer risk following lifetime exposure to 1/6 of the maximum level of total chromium measured by VADEQ (0.00393 ug/m<sup>3</sup>) would be 7.9 in 1,000,000, representing a slight increase in the risk for developing cancer. ATSDR further notes that, similar to the information for arsenic, the measured concentrations of total chromium in the VADEQ sampling event are comparable to “background” levels documented in multiple scientific studies (ATSDR 2008).

## **Conclusions and Recommendations**

### Conclusion

Based on all of the above information, ATSDR concludes that Roda residents exposed to particulate matter at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM<sub>10</sub> particulate consisted of PM<sub>2.5</sub>. Given the subsequent measures taken to control dust along the road and the reduction in mining activities and associated truck traffic in the community, we do not know if particulate levels presently remain a public health concern for Roda residents.

There are significant data gaps that prevent ATSDR from evaluating exposures and predicting the likelihood of actual health effects for the residents along Roda Road. In general, the 2008-2009 air

monitoring information provides a snapshot in time of conditions existing in the recent past that may not be representative of current conditions. Data quality issues and concerns about non-mining related air quality influences during the sampling periods (e.g., roadwork and data collection concerns in 2008 and potential burning activities in 2009) contribute to the uncertainty in this evaluation. Further, an important specific data gap is the lack of sampling information for smaller particulate matter (i.e., particulate matter less than less than 2.5 micrometers in diameter (PM<sub>2.5</sub>) and ultrafine particles), and the lack of receptor-specific monitoring locations and/or personal monitoring that could define short-term exposures during high intensity mining/truck traffic periods.

Based on ATSDR's screening of the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks; the levels found are comparable to "background" levels for these metals in U.S. air.

### Recommendations

1. Federal, state and local agencies in the area should continue to take any available measures (including effective implementation of the VADMME/VADEQ MOA) to reduce particulate matter and dust emissions affecting the residential areas along Roda Road, and in other areas with similar conditions in the state.

ATSDR understands and appreciates that VADEQ is already engaged in longer term efforts with railroad and state authorities to potentially improve Roda Road. VADEQ and VADMME should continue efforts with the mining companies to minimize the residential impact of the truck emissions in affected areas like Roda or similar communities (e.g., diverting traffic to alternate roads if possible, continuing/enhancing road dust control measures involving water trucks, roadway sweepers and truck washes, instituting clean diesel controls on trucks using the road, etc). Mining activities are coming to a close in the Roda area. However, ATSDR encourages VADEQ to use the experiences gained from this site to proactively implement similar particulate matter and dust exposure reduction activities in other communities with similar air quality concerns from mining/trucking activities.

2. If the State Air Pollution Control Board finds that the MOA is not being effective in addressing the air quality concerns at Roda or other similar sites, ATSDR recommends that VADEQ consider additional environmental assessment efforts. Options VADEQ should consider include:
  - Additional environmental sampling of the fine particulate matter fraction (PM<sub>2.5</sub> monitoring) in the air of the community. ATSDR recommends that if this sampling is conducted, that it be designed to be receptor-specific (e.g., personal-type monitoring and/or ambient monitors in yards close to the road) as opposed to NAAQS-based, in order to fully address the cumulative exposures from mining and diesel exhaust in the community.
  - Real time air monitoring of PM<sub>2.5</sub> and PM<sub>10</sub> to determine peaks near the receptor population.
  - Further laboratory analysis of samples collected in VADEQ's prior sampling event in Roda to generate empirical data to determine what percentage of the Roda particulate matter is coal dust.
  - Documenting with the mining company the number of trucks using Roda Road or other similar affected haul roads per day/week/month/year, and estimating changes in diesel emissions and subsequent community exposures based on truck volume.
3. Residents in the most impacted homes should consider personal health-protective steps to limit their particulate matter exposures, and discuss personal health concerns with a health care professional. Examples of personal health-protective steps include:
  - If particle levels are high outside, keep windows and doors closed. If needed for comfort, use air conditioners or heating systems on recycle/recirculation mode, if available. Inspect and change filters often in home systems.

- When the air quality improves (e.g., on the weekends when truck traffic is reduced), open up and air out the home.
- Reduce indoor sources of particles, including: propane/wood/coal burning stoves and furnaces, natural gas stoves and ovens, and gas logs. Activities such as cooking, burning candles, and tobacco smoking greatly increase the particle levels in a home. Even vacuuming can stir up and greatly increase particle levels in the air.
- Residential trash burning is a source of harmful air emissions. Residents are strongly encouraged to haul trash to approved facilities, or at a minimum to limit this activity in close proximity to homes and people.
- Consider using a vacuum cleaner with a "high efficiency particulate arresting" or HEPA filter, if available.
- Some air cleaners can be effective at reducing indoor particulate levels, but they must properly be matched to the size of the space to be cleaned. Keep these devices clean and the filters changed frequently.
- Wipe floors and hard surfaces with a damp mop or cloth that will retain the dust.
- Sensitive individuals with heart or lung disease, the elderly, and children should consider the following additional measures
  - On particularly dusty days, limit time outdoors.
  - Avoid physical exertion, indoors or outdoors, when particulate matter levels are high.
  - If you have symptoms of heart or lung disease, including shortness of breath, chest tightness, chest pain, palpitations or unusual fatigue, contact your health care provider.
  - If you have heart or lung diseases, make sure you have adequate medication on hand. If you have asthma, be sure to follow your asthma management plan (EPA 2007).

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John  
Pomponio/R3/USEPA/US  
11/18/2010 05:16 PM

To Jeffrey Lapp  
cc  
bcc  
Subject Fw: GAO report on EPA's MTM permit review released

Jeff,

Let's discuss. I read the report. No big surprises. Some misconceptions.

John R. (Randy) Pomponio, Director  
Environmental Assessment & Innovation Division  
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----- Forwarded by John Pomponio/R3/USEPA/US on 11/18/2010 05:15 PM -----

From: Jessica Greathouse/R3/USEPA/US  
To: Shawn Garvin/R3/USEPA/US@EPA, William Early/R3/USEPA/US, John Pomponio/R3/USEPA/US@EPA, Catherine Libertz/R3/USEPA/US@EPA, Michael Kulik/R3/USEPA/US@EPA, Jon Capacasa/R3/USEPA/US@EPA, Donna Heron/R3/USEPA/US@EPA, LaRonda Koffi/R3/USEPA/US@EPA, Megan Mackey/R3/USEPA/US, Michael Dunn/R3/USEPA/US@EPA, John Forren/R3/USEPA/US@EPA, Stefania Shamet/R3/USEPA/US@EPA, Jessica Martinsen/R3/USEPA/US@EPA, Jeffrey Lapp/R3/USEPA/US@EPA, Daniel Ryan/R3/USEPA/US@EPA, Amie Howell/R3/USEPA/US@EPA, Samantha Beers/R3/USEPA/US@EPA  
Date: 11/18/2010 03:45 PM  
Subject: GAO report on EPA's MTM permit review released

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The report is on the GAO website at <http://www.gao.gov/new.items/d11101r.pdf>. The Coal Tattoo has also made its first analysis.

Jessica H. Greathouse  
State and Congressional Liaison  
U.S. Environmental Protection Agency  
(304) 224-3181

**Melissa**  
**Gebien/R5/USEPA/US**  
11/19/2010 01:40 PM

To Christopher Hunter  
cc Wendy Melgin, Peter Swenson  
bcc  
Subject Bear Run Amendment 4 permit application

Hi Chris-

Here's a copy of the Bear Run Amendment 4 permit application for your reference. The details regarding mitigation can be located at pages 58-86 of the permit.

\*Part 1 of 9/10/10 revision of Bear Run Amendment 4 Permit  
revision of Bear Run Amendment 4 Permit

\*Part 2 of 9/10/10



03\_ACDE Permit Data\_Bear Run Mine \_Amendment 4\_\_09-10-10\_BLUE .pdf



03\_ACDE Permit Data\_Bear Run Mine \_Amendment 4\_\_09-10-10\_BLUE\_pages 38-88 .pdf

Appendix J to the permit includes details regarding the off-site mitigation proposed.



13\_Appendix J\_Buttermilk Creek Mitigation Plan\_09-10-10.pdf



13\_Appendix J\_Buttermilk Creek Mitigation Plan Map\_09-10-10.pdf

Thanks and have a great weekend-

Melissa

**Bear Run Mine (AMDT 4) 404 ID No. LRL-2010-193-gjd**  
**Supplemental Off-site Mitigation Plan for Buttermilk Creek**  
**September 10, 2010**

**Introduction:** To develop supplemental off-site mitigation to compensate for temporal impacts to wetlands and streams involved with operation of Bear Run Mine (AMDT 4) 404 permit ID No. LRL-2010-193-gjd. This plan was developed by Wetland Services and the Peabody Midwest Environmental Services Group in consultation with Dr. Jeff Barry of Arcadis U.S. who performed the HEC-RAZ floodway modeling and provided technical input (see attached memo).

**Location:** From U.S. Hwy 41N in Sullivan, Indiana proceed east on SR54 2.4 miles to CR200E. Proceed south on CR 200E 0.6 mile to the NE corner of the site (see attached aerial photo-based map).

**Responsible Parties:**

<b>Applicant</b>	<b>Contact</b>	<b>Property Owner(s)</b>
Peabody Midwest Mining LLC 7100 Eagle Crest Boulevard Evansville, IN 47715-8152	Bryce West 812-434-8580	American Land Holdings of Indiana LLC

**Site Description:** The Buttermilk Creek site is situated in the U.S.G.S. Middle Wabash-Busseron Watershed, 8-Digit HUC 05120111. This site is oriented as a cross-section of Buttermilk valley encompassing 5,500 feet of the abandoned original oxbow stream channel. The following information was derived by remote sensing, GIS, on-site reconnaissance, sampling and GPS and conventional based-surveying. Information was also gathered from local neighbors with extensive knowledge of the site and surrounding area.

- 1. Land use:** The parent parcel is 355 acres. Land use on the larger parent area consists of approximately 220 acres of cropland, 1 acre of grain bins, 11 acres of dry woods, 123 acres of wet woods, drains, dredged channels and diversions. In 1971 an additional 34 acres of cropland were in production. Today these areas exist as wet woods, and were likely abandoned due to marginal productivity. On site this condition is evidenced by an even-aged monoculture of early-successional soft mast trees that are approximately 30 years old, as well as old ditches.
- 2. Hydrology:** Extensive drainage efforts have been applied to this site over time. These hydrologic impacts include dredged channels, diversions and tile. These efforts are evidenced by deep, straight channels with steep spoil banks. Approximately 9,000 feet of excavated surface drains have been identified and targeted for some degree of removal. Hydrologic inputs to the site are mainly Buttermilk Creek with an upstream drainage area of 10 square miles. The main landuse in the upper watershed is reclaimed surface mine with many large basins surrounded by forest and wildlife plantings. Agriculture is limited in the upper watershed with all runoff passing through one or more impoundments. These impoundments store water and provide for a relatively strong, clean and consistent base flow. Storm surge on this site is ameliorated by these many surface impoundments as well as the adjacent forest with extensive floodplain. Just prior to entering the site, Buttermilk Creek flows through 2,200 feet of bottomland forest. Lastly with respect to hydrology, this site is the transition area or

interface between headwater flooding from upstream and backwater from Busseron Creek during significant flood events. This information was derived from several locals who knew that CR200 flooded frequently while CR275 had never flooded. This information also is consistent with the HEC-RAS model.

3. **Soils:** The majority of the site is developed in hydric soils. Stendal makes up the majority of the floodplain with Cuba immediately adjacent to Buttermilk Creek. Henshaw occurs in the upland drains with Ava and Iva on the upland slopes to the north and south.
4. **Climate** in the Illinois Basin South as of 2003 at 400'ASL: 45" rain, 14" snow, Mean annual temp is 55.6°F, Average daily extreme temp is 87.3 °F and 22 °F.
5. **Aquatic Resource Functions** considered in this mitigation include water quality, sediment transport, habitat and nutrient cycling. Existing habitat and water quality functions are presented in the Bio-assessment report. Nutrient cycling, as a component of water quality can also be extrapolated from the Bio-assessment report. The projected stream velocity changes are detailed in a table with the profile drawings of each station.
6. **Timing:** Mitigation on this site will occur long before the vast majority of impacts occur on Bear Run 4 mining area, greatly off-setting temporal loss. The offset of temporal loss and the likelihood of success on this site are high. Mitigation will be completed by the end of the 2<sup>nd</sup> growing season following permit issuance.

**Mitigation Objectives and Approach:** The purpose of this section is to describe the general strategies that will be applied to the various site conditions and landuses. Total mitigation generated on this site includes 18,100 feet of stream, 60 acres of wetland and 8 acres of upland buffer mitigation. The objective is to produce a high level of stream and wetland function, with a high degree of stream and wetland interaction. This restoration approach maximizes the development of aquatic ecosystem area and function by orienting the individual hydrologic components – streams and wetlands in a manner conducive to landscape connectivity and complimentary function. Because the floodplain is prior converted cropland it is expected to develop strong wetland characteristics. With maturity the stream and wetland together will function more as a flowing aquatic ecosystem. Aside from being large and contiguous, many physical, chemical and biological aquatic ecosystem functions are enhanced by this design as the stream and wetland each provide their unique benefits simultaneously and complimentary.

1. **Stream** mitigation begins with the reactivation of the 5,500 feet of original stream oxbow adjacent to the existing channel. Reactivation will occur by reconnecting the upper on-site watershed to the original meandering oxbow channel and also directing the existing main channel into the oxbox channel using earthen and rock plugs (see attached conceptual design). On the map this can be seen at Plug 'A' where the upper on-site drainage flowpath color changes from dark blue to teal and for the redirected Buttermilk Creek drainage this can be seen where the flowpath channel becomes teal. Increased on-site drainage will also be redirected to the oxbow channel at the location of Plug 'B'. The additional and redirected flow will give a considerable increase in stream function produced in this mitigation site. It will also increase wetland hydrology across the floodplain, but not to an extent detrimental to the existing forest. Since abandonment, some limited areas of saplings and brush have grown up that should be removed. Stream mitigation continues with 12,000 feet of Priority 1 construction in cropland

valleys. About 2,000 feet will be higher gradient B-channels with the remaining 10,000 feet being lower gradient and larger C- and E-channels. These channels will exist within newly established PFO wetland. 600 feet of in-stream structure enhancement is proposed for an existing stream in the NE wooded corner. This section begins with mass wasting and instability below a larger culvert leading into the site.

2. **Wetland** mitigation includes 60 acres of PFO construction on existing cropland. A limited amount of excavation will be conducted to remove diversions and fill in old ditches. This excavation will be in conjunction with construction of the Priority 1 stream channels that will run through these areas. An additional 8 acres of Riparian buffer creation will occur as upland vegetation along higher gradient streams.

#### Mitigation Compensation and Timing:

Table 3: Wetland acres generated		Table 3A: Stream linear footage generated		Table 3B: Upland Buffer acres generated	
PFO Creation*	60 ac	Stream Creation	12,000 ft	Upland Riparian Buffer Creation	8 ac
		Buttermilk Restoration	5,500 ft		
		In-Stream Structure Enhancement	600 ft		
*Some created wetlands will also function as lowland riparian buffers.					
Plantings, Restoration, etc. will be completed by the end of the 2 <sup>nd</sup> growing season following permit issuance.					

**Construction** must be completed under suitable field conditions.

1. **Excavation** during excessively wet or dry conditions reduces the quality of the end product and increases the risk of failure. In extreme circumstances (such as record wet or dry growing seasons) construction may have to be postponed until the following year. Operating heavy equipment in ecologically sensitive areas requires knowledge of heavy equipment operation, soil stratification, plant identification, and strict attention to detail. Well-trained personnel will be onsite during all phases of construction to ensure restoration objectives are met with minimum disturbance. Equipment used may include dozers, skidders, pumps, track hoes, back hoes, scrapers, pans, trucks and pay-loaders.
2. **Surface Roughening** is the use of a bog or crosscut disc to leave the land surface highly textured. This approach is effective when attempting to promote surface hydrology above pool margins or on flat plains. Surface roughening promotes ponding by reducing runoff and creating many micro-depressions intermixed with large clods. Clods provide shade and block wind to reduce evaporation. Clods also provide 360<sup>0</sup>

aspect to promote plant diversity including mosses and lichens, especially in wet meadows. Surface roughening is also a good weed control technique when managing undesirable species between tree rows. It allows effective weed control while also enhancing hydrology. Herbaceous species rapidly recover and often in better condition.

3. **Soil conditioning** is necessary to reduce compaction, remove weeds, incorporate soil amendments and prepare a seedbed conducive to good seed to soil contact.
4. **Planting** is the most expensive and failure-prone step in restoration. Site-specific conditions of microtopography and hydroperiod will guide the final planting and management process. All plant materials will be maintained in proper conditions such as refrigeration, stratification, dormant, wet or dry as appropriate until planted. Planting will occur during optimum field conditions and in a manner suitable for establishment of the specific propagule type.

**Challenges** anticipated for mitigation success on this site are generally limited to excessively wet conditions and fertility and tilth of the growing substrate relevant to vegetation establishment and survival.

1. **Fertility:** Deep tillage and surface roughening will promote water storage in the upper soil profile. Soil amendments including lime and fertilizer will be applied to create a suitable growing environment for the target species.
2. **Non-Target Species (invasive, exotic or volunteer)** invasion and control should be limited as the planting sites are currently under intensive agriculture; they are essentially a blank pallet with no phragmites, etc. on site. Problems with the establishment of undesirable plant species in forested areas will typically be controlled with herbicide sprayed on the rows and mechanical removal between rows. Methods to control undesirable species include but are not limited to mechanical removal by logging, chopping, chipping, bush hogging, cutting, girdling, grinding, burning, herbicide, flooding and desiccation. Beneficial volunteer species may be maintained on site with approval from the ACOE.
3. **Hydrology** is expected to be very sufficient and periodically excessive. Head and backwater flooding, ponding and high water tables may sometimes delay certain activities while simultaneously promote vigorous establishment of target species. Temporary diversions may be used. Generally however, no problems are anticipated with hydrology.
4. **Erosion** in newly constructed streams will be ameliorated by maintaining low slopes via surface shaping in increased channel sinuosity. Erosion control blankets, hydromulch and mats may be used in conjunction with other bio-engineering methods. Timely establishment of vegetation will provide long-term stability.

**Contingency Plan:** Actions in Contingency are similar to those previously detailed in the Construction and Challenges sections. If other success criteria are not met for all or any portions of the compensatory mitigation project in any year, and/or if the success criteria are not satisfied, the permittee will prepare an analysis of the cause(s) of failure and propose remedial action for pre-approval. Ecologically this site is completely suited for establishment of the proposed mitigation. Should problems arise that compromise long-term success, the applicant

will report to the ACOE and based on available information revise the mitigation plan to facilitate successful conditions.

Vegetation plantings, monitoring, success criteria, long-term management and protection will be the same as those set forth in Bear Run Mine (AMDT 4) 404 permit application ID No. LRL-2010-193-gjd.

### **Stream Plan**

**Goal:** To construct a natural stream channel that can develop free-form, self-sustaining conditions. This approach is derived from the best and most current Rosgen-based scientific methods. This program was modified specific to Midwestern reference conditions including Indiana.

**Reference:** This process is derived from a scientific approach to natural channel design. All design parameters are based on optimum reference conditions throughout the region. Channel sizing is based on the watershed area of the stream. Channel area is derived from Regional curve data and sized for a natural bankfull return interval. Channel area is applied to a specific width/depth ratio. All other parameters are set, by ratio, to either Wbkf or Dbkf.

#### **Instructions:**

1. **Alluvial Valley:** It is necessary that the valley be wide enough to accommodate the Wfpa which is generally 10X Wbkf. The lower gradients in alluvial valleys facilitate groundwater infiltration that drives intermittent stream conditions. The valley also provides a corridor for the stream to meander and develop free-form morphology. Stream design varies with channel slope; 0-1.3% for C-channels, 1.3-3% for B-channels.
2. **Materials:** Topsoil, rock and coarse woody debris (trees and root wads) should be logistically timed and placed on site for construction. Filter fabric, seed, mulch, erosion blanket, pins and rebar are also necessary. Never dig more open channel than can be quickly completed.
3. **Channel Construction:** Channel construction will be performed to accomplish: a). improved channel morphology within the original meandering oxbow and b). on-site stream drainages. To improve the original meandering channel morphology, some small trees and areas of excessive sediment deposition will need to be removed to create and enhance on-site streams; the basic channel will be constructed with a set width and depth that increases as the stream moves down valley. This step includes the construction of the basic channel. It is recommended that construction be conducted so as to make a precise cut with minimal peripheral disturbance. Once the stakes are set it is recommended that a hurricane ditcher be used to make the initial cut to grade depth. Hurricane ditchers are tractor mounted PTO driven devices that can be set to a precise depth. These units can be easily navigated around staked corners to produce sinuosity. Finally they discharge the cut material in a "rooster tail" manner that evenly distributes the cut material across the flood prone area without restricting the streams floodplain access or causing damage to established vegetation. An excavator can then be used to make final width and side slopes.

4. **Pool Construction:** Pools are deeper than the riffle sections of the stream. Pools should be excavated to design specs located in Step 3 – Profile. Excess material should be disposed offsite or graded flat in a manner that will not restrict floodplain access.
5. **Riffle Structures** serve the main function of grade control. As such, these features must be designed for sustainable scouring during high velocity flows. The design and installation of riffle structures varies between B-channels and C-channels.
  - A. **B-channel** riffle structures consist of a log(s) keyed across the channel. Refer to the drawing in Step 3 Riffle Construction B-channels.
  - B. **C-channel** riffle structures consist of the appropriate sized material (fine gravel, coarse gravel, etc.) as determined by shear-stress calculations. Refer to the drawings in Step 3 Riffle Construction C-channels.
6. **Coarse Woody Debris:** Install log vanes leading into meander bends and root wad revetments around the meander bends as detailed in Step 4.
7. **Planting and Erosion Control:** These steps occur simultaneously. Be prepared, the 100-year event will likely occur the day after construction.
  - A. Apply lime, fertilizer and seed to exposed stream banks.
  - B. Apply appropriate erosion control (mulch, blankets, matting, etc).
  - C. Install live stakes at specified locations.
  - D. Plant the riparian zone in trees only after the stream has established good bank vegetation and is stabilized. Stream maintenance activities will damage riparian trees if planted too early.
  - E. Following construction the riparian buffer will be planted with hard mast bare root seedlings at a rate of 600 stems/acre, and the herbaceous understory rate and species listed in the Bear Run 4 permit.
8. **Monitoring Stations:** Establish monitoring stations according to criteria set forth in the Mitigation portion of this document.

### **Design Parameters: C-channel (meandering) 0-1.3% slope**

#### ***Riffle cross-section:***

Cross-sectional area: from regional curve regression equation,  $43.474 \cdot A^{0.5222}$ , where A is the watershed area in square miles

Width/depth (W/D) ratio: 15

Channel side slope: 3:1

Bankfull (top) width: calculated from cross-sectional area and W/D ratio

Mean bankfull depth: calculated from cross-sectional area and W/D ratio

Maximum bankfull depth: calculated from channel width, side slope, and area

Bottom width: calculated from channel depth, side slope, and area

#### ***Pool cross-section:***

Point bar slope: 6:1

Pool depth: 2X maximum riffle depth

Pool bottom width: same as riffle bottom width

Pool top width: calculated from bottom width, depth, side slope, and point bar slope

***Longitudinal profile:***

Riffle length: 2X bankfull width

Pool length: same as riffle length

Run length: half of riffle length

Glide length: half of riffle length

Depth at end of run: one-third of elevation change between riffle and pool depths

Depth at head of glide: two-thirds of elevation change between pool and riffle depths

***Plan view:***

Sinuosity: 1.3

Floodplain width: 10X bankfull width

Meander length: 9X bankfull width

Beltwidth: calculated from sinuosity, meander length, and bankfull width

***Channel lining specifications:***

Shear stress: product of channel slope, bankfull maximum depth, and weight of water (62.4 lbs/cubic foot)

Velocity: from Manning's equation, with Manning's  $n = 0.035$

d100 particle size: estimated (in millimeters) from a Rosgen regression equation:

$152.02 \cdot x^{0.7355}$ , where  $x$  equals the shear stress.

**Design Parameters B-channel (Step Pool) 1.3-3% slope*****Riffle cross-section:***

Cross-sectional area: from regional curve regression equation,  $43.474 \cdot A^{0.5222}$ , where  $A$  is the watershed area in square miles

Width/depth (W/D) ratio: 15

Channel side slope: 3:1

Bankfull (top) width: calculated from cross-sectional area and W/D ratio

Mean bankfull depth: calculated from cross-sectional area and W/D ratio

Maximum bankfull depth: calculated from channel width, side slope, and area

Bottom width: calculated from channel depth, side slope, and area

***Pool cross-section:***

Channel side slope: 2:1

Pool depth: 2X maximum riffle depth

Pool top width: same as riffle top width

Pool bottom width: calculated from pool top width, side slope, and depth

***Longitudinal profile:***

Step height: 0.33 feet

Riffle length: calculated from channel slope and step height

Pool length: same as riffle length

***Plan view:***

Sinuosity: 1.1

Floodplain width: 10X bankfull width

Meander length: calculated from sinuosity, pool length, and riffle length

Beltwidth: calculated from sinuosity, meander length, and bankfull width

**Channel lining specifications:**

Shear stress: product of channel slope, bankfull maximum depth, and weight of water (62.4 lbs/cubic foot)

Velocity: from Manning's equation, with Manning's  $n = 0.035$

d100 particle size: estimated (in millimeters) from a regression equation from Rosgen:

$152.02 \cdot x^{0.7355}$ , where  $x$  equals the shear stress

## WETLAND PLAN

**Wetland Specifics:** This plan proposes to create 60 acres of PFO wetland.

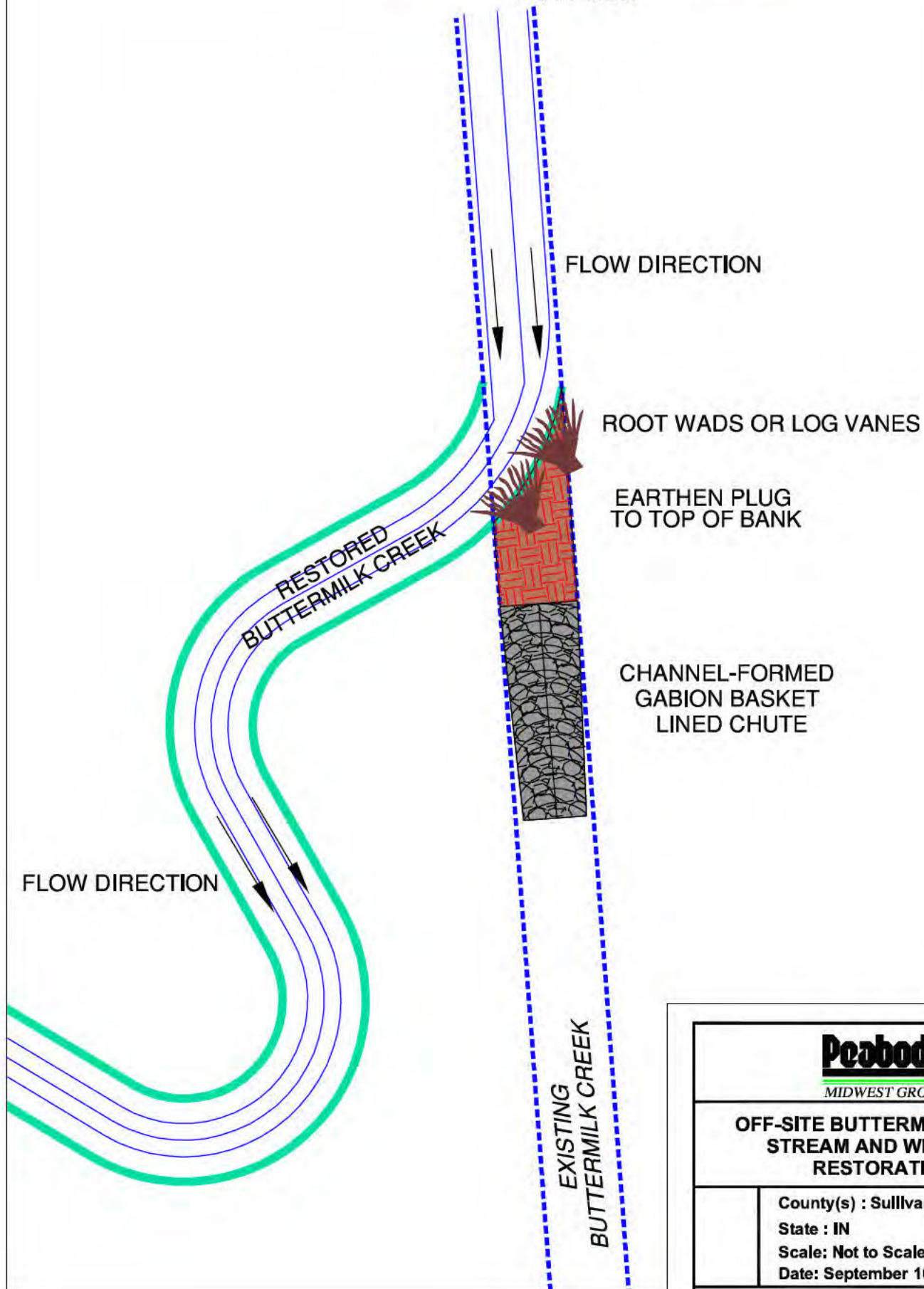
**Mitigation Goals and Objectives:** These wetland mitigation areas will be developed in the flood prone area of multiple low gradient mitigation streams. Overbank flooding will occupy the floodplain to service the adjacent wetlands. Overflow will be trapped and stored on the floodplain where it will then be cleaned up and metered back into the stream to help drive more intermittent stream flow conditions. The ultimate goal of the project is to restore a self-sustaining riparian system that is well developed in target native vegetation so as to provide clean water and high quality habitat.

- 1. Site Selection and Justification:** This site was chosen because it provides the largest ecological lift in the watershed compared to other potential sites.
- 2. Hydrology:** The combination of the following two sources will provide frequency and duration optimal to support hydrology levels A, B, C, D and E as defined by the Cowardin classification system. Plantings will be specific to this range of hydrology; with FAC+ species in the more temporarily flooded areas, OBL in the more seasonally flooded areas and FACW making up the transition
  - A. Runoff Retention Ratio:** With minor excavation to remove diversions and ditches, these mitigation areas will receive laminar upland runoff from a cumulative total of 188 acres. 60 acres of wetland supplied by 188 acres of runoff gives a runoff retention ratio of 3.1:1. Combined with overbank flooding and saturated conditions, this site will provide very suitable hydrology for PFO. Cumulative watershed total leaving the site at 6,750 acres.
  - B. Overbank Flooding** from the Oxbow and Priority 1 stream construction will occur on a frequency and distribution specific for development of PFO wetland.

**Schedule:** Restoration activities will begin immediately with permit issuance. Following construction the wetland will be planted with hard mast bare root seedlings at a rate of 600 stems per acre, and the herbaceous understory species listed in Bear Run Mine (AMDT 4) 404 permit application ID No. LRL-2010-193-gjd.

## BUTTERMILK CREEK PLUG "A" DETAIL

PLAN VIEW



**Peabody**

MIDWEST GROUP

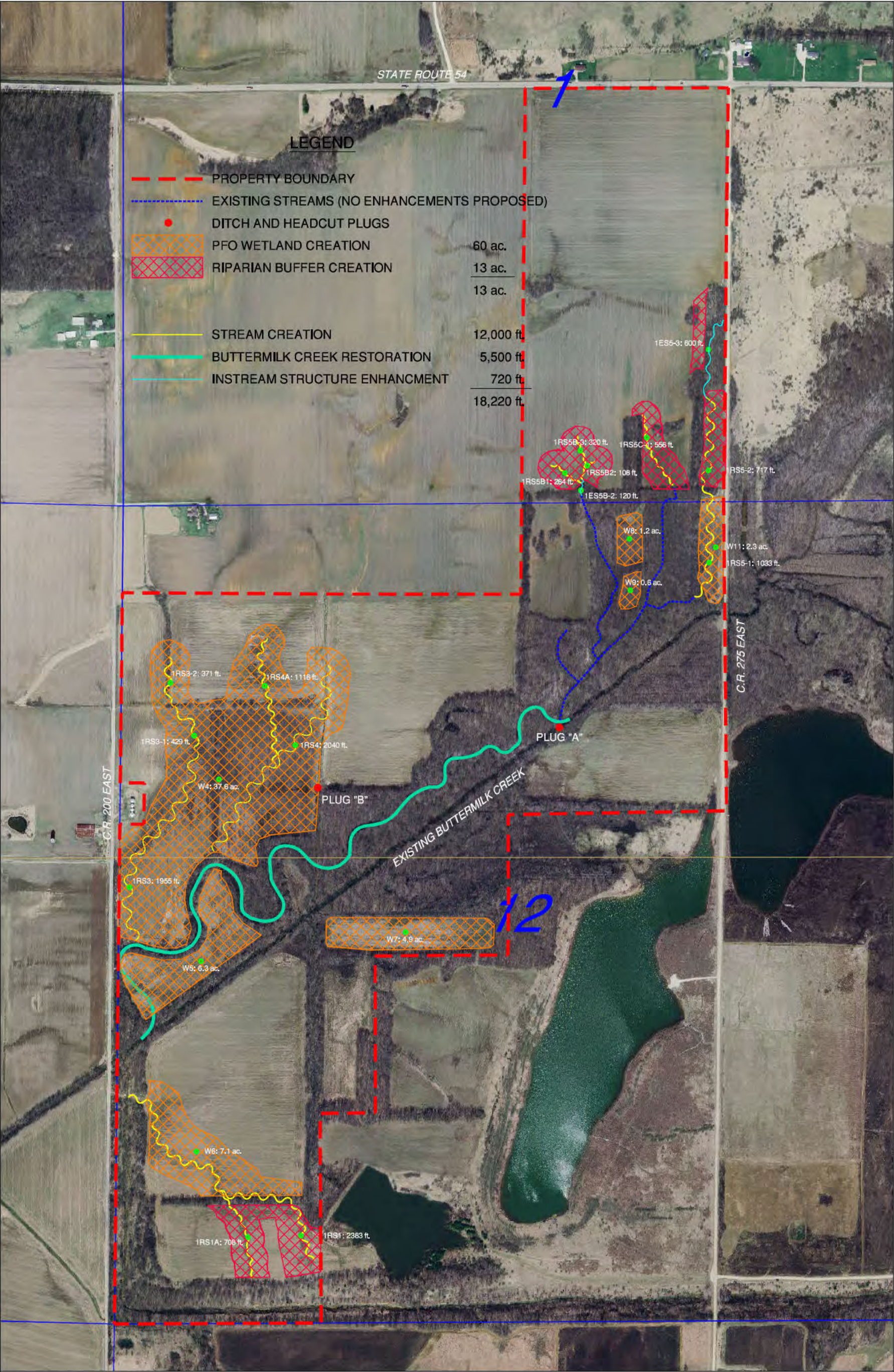
### OFF-SITE BUTTERMILK CREEK STREAM AND WETLAND RESTORATION

County(s) : Sullivan

State : IN

Scale: Not to Scale

Date: September 10, 2010



STREAM NAME	CHANNEL TYPE	SINUOSITY	AVERAGE SLOPE	STREAM LENGTH (feet)	DRAINAGE AREA (acres)	WAVELENGTH (feet)	Xsec AREA (sq. ft.)	WIDTH	DEPTH	AVERAGE VELOCITY (ft/sec)	SHEAR STRESS (lbs/sq. ft.)	BANKFULL DISCHARGE (CFS)
1RS1	C (riffle-run-pool)	1.30	0.3%	2383	33	106.3	9.3	11.8	1.1	2.11	0.07	19.7
1RS1A	B (step-pool)	1.10	2.2%	708	7	70.1	4.0	7.8	0.7	2.91	0.14	11.8
1RS3	C (riffle-run-pool)	1.40	0.1%	1955	108	144.2	17.1	16.0	1.5	0.63	0.01	10.8
1RS3-1	C (riffle-run-pool)	1.30	0.7%	429	82	134.6	14.9	15.0	1.4	1.95	0.06	29.1
1RS3-2	C (riffle-run-pool)	1.30	0.6%	371	59	123.7	12.6	13.7	1.3	1.82	0.05	22.9
1RS4	C (riffle-run-pool)	1.40	0.2%	2040	114	146.4	17.6	16.3	1.5	1.17	0.02	20.7
1RS4A	C (riffle-run-pool)	1.30	0.2%	1116	13	84.3	5.8	9.4	0.9	0.80	0.01	4.7
1RS5-1	C (riffle-run-pool)	1.30	0.3%	1033	66	128.1	13.5	14.2	1.3	1.23	0.02	16.7
1RS5-2	C (riffle-run-pool)	1.30	1.0%	717	84	126.2	13.1	14.0	1.3	2.32	0.08	30.4
1RS5B1	B (step-pool)	1.10	2.3%	264	2	51.0	2.1	5.7	0.5	2.73	0.12	5.8
1RS5B2	B (step-pool)	1.10	3.9%	108	1	41.5	1.4	4.6	0.4	3.44	0.20	4.9
1RS5B-3	B (step-pool)	1.10	2.3%	320	3	59.0	2.9	6.6	0.6	2.83	0.13	8.1
1RS5C-1	B (step-pool)	1.10	3.9%	556	7	70.8	4.1	7.9	0.7	3.84	0.24	15.9

Figure 3: IDEM macroinvertebrate and fish sampling locations within the northern half of the Middle Wabash - Busseron watershed.

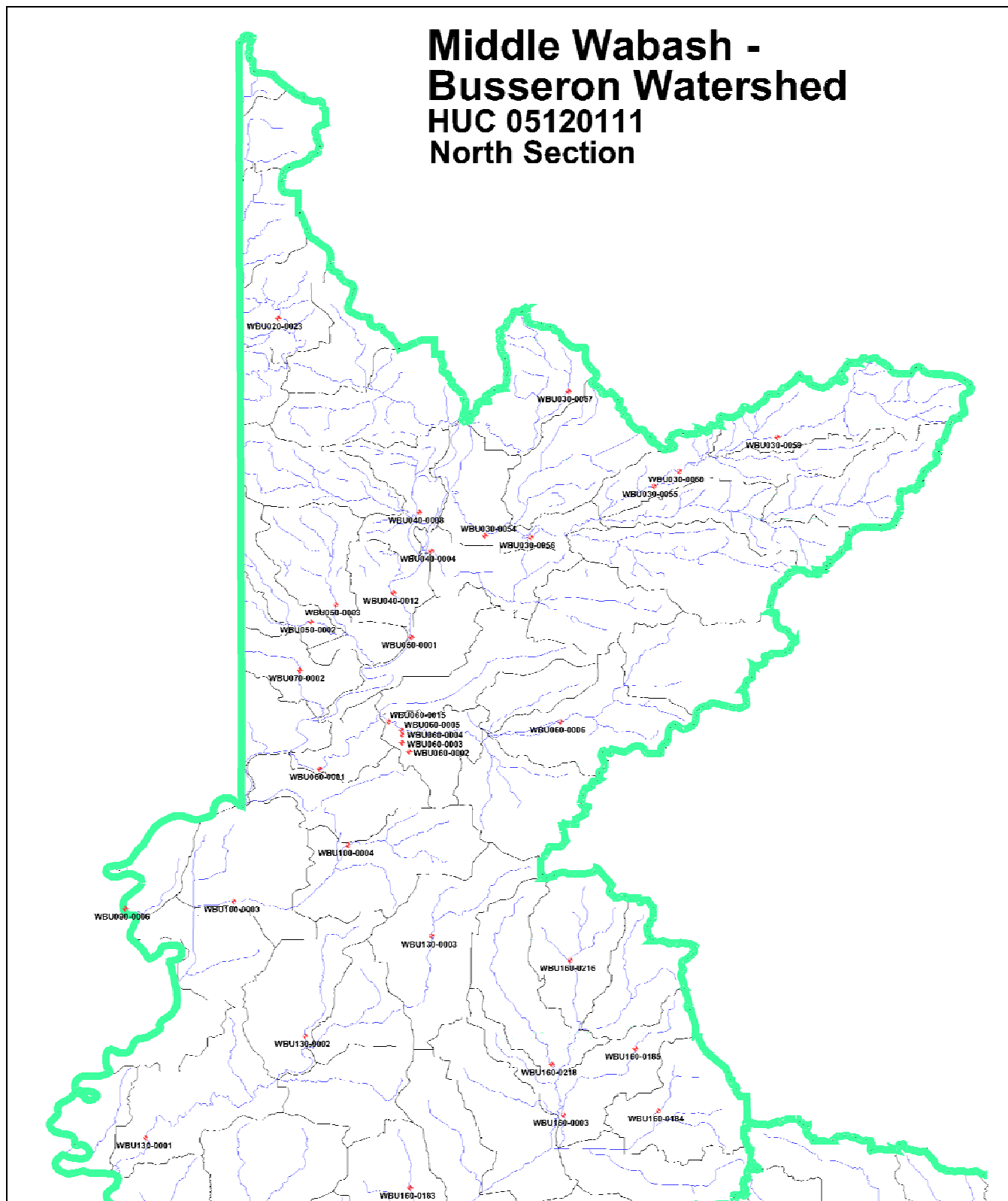


Figure 4: IDEM macroinvertebrate and fish sampling locations within the southern half of the Middle Wabash - Busseron watershed. Bear Run permit area shown in red.

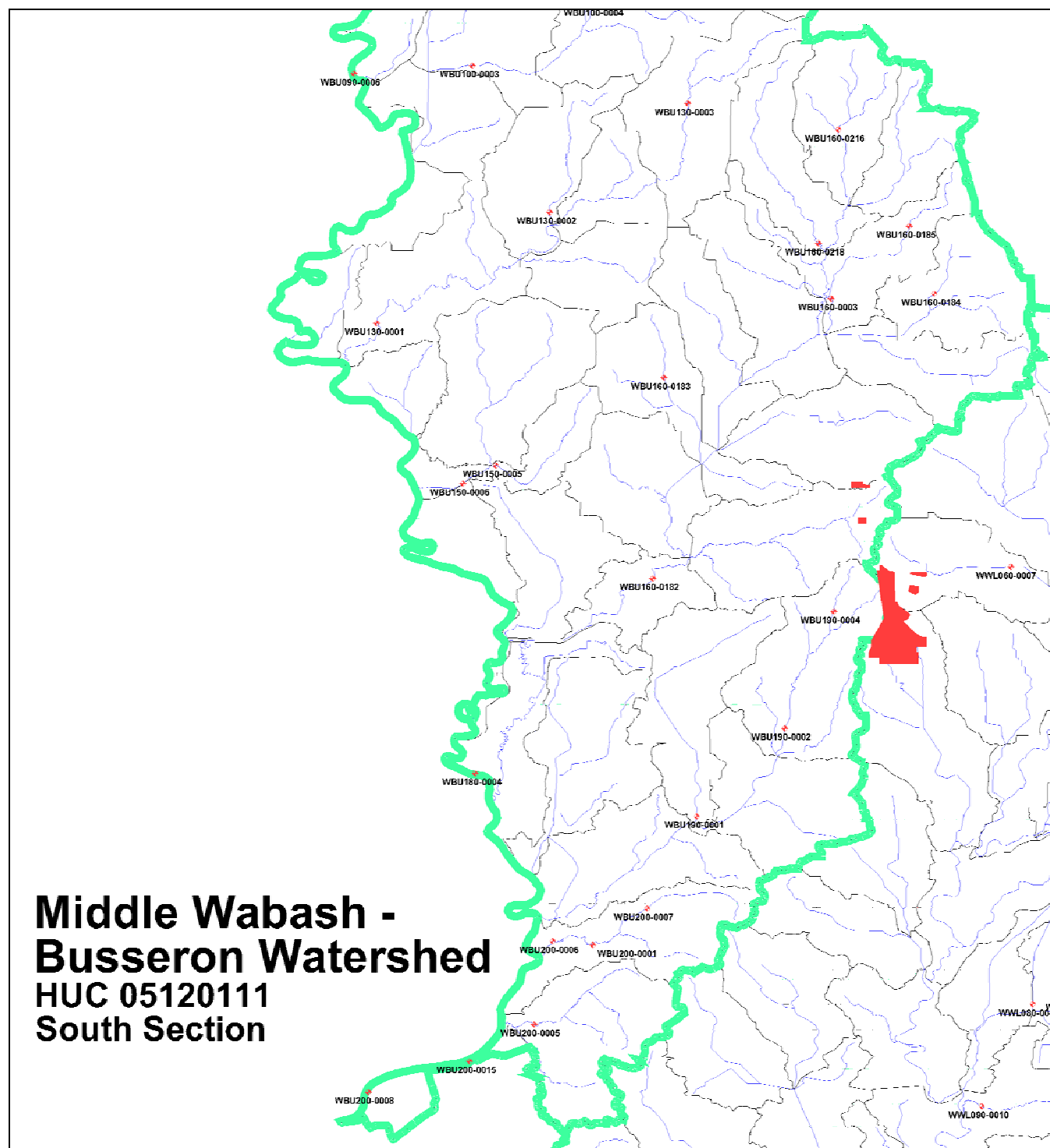


Figure 5: IDEM macroinvertebrate and fish sampling locations within the immediate vicinity of the Bear Run permit area.

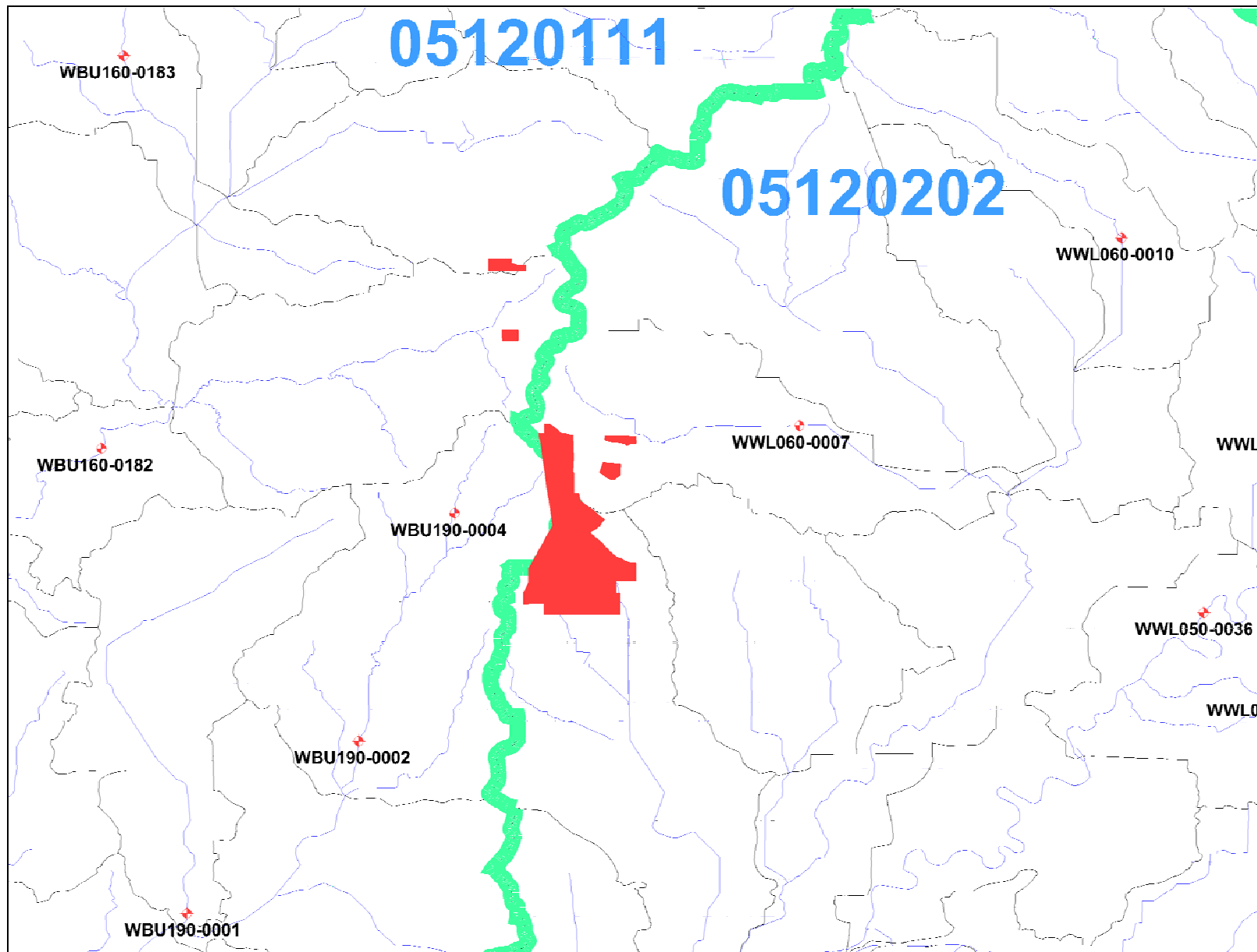


Table 1: IDEM QHEI assessment scores within the Middle Wabash - Busseron watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sampling Section	Sample Date	Stream Name	HUC 14	Substrate Score	Stream Cover Score	Channel Score	Riparian Score	Pool Glide Score	Riffle Run Score	Gradient Score	QHEI Total Score
WBU020-0023	Fish	06/29/2004	Brouillets Creek	05120111020020	13	17	15	4	10	5	8	72
WBU030-0056	Fish	08/09/1999	Otter Creek	05120111030080	13	10	19	10	8	0	10	70
WBU030-0059	Fish	06/28/2004	North Branch Otter Creek	05120111030040	11	14	14	7	11	3	10	70
WBU030-0060	Fish	06/28/2004	North Branch Otter Creek	05120111030050	13	14	14	9	10	4	6	70
WBU030-0067	Fish	07/29/2004	Spring Creek	05120111030010	14	9	14	8	5	2	8	60
WBU030-0067	Fish	07/29/2004	Spring Creek	05120111030010	15	12	15	10	4	3	8	67
WBU040-0004	Fish	08/09/1999	Lost Creek	05120111040040	15	6	13	9	5	3	8	59
WBU040-0012	Fish	09/15/1999	Wabash River	05120111040050	15	7	14	8	10	0	6	60
WBU060-0015	Fish	07/06/2004	Honey Creek	05120111060050	13	13	16	10	10	5	6	73
WBU090-0006	Fish	09/27/2004	Wabash River	05120111090040	11	14	12	6	10	0	8	61
WBU090-0006	Fish	10/13/2004	Wabash River	05120111090040	11	14	12	6	10	0	8	61
WBU150-0006	Fish	08/09/1999	Turtle Creek	05120111150030	13	6	11	9	5	0	6	50
WBU160-0003	Fish	08/09/1999	Busseron Creek	05120111160040	3	17	16	9	9	0	6	60
WBU160-0003	Fish	09/01/1999	Busseron Creek	05120111160040	3	13	14	6	9	1	6	52
WBU160-0216	Fish	06/30/2004	Busseron Creek	05120111160010	16	12	12	5	3	2	8	58
WBU160-0218	Fish	06/30/2004	Busseron Creek West Fork	05120111160030	11	13	14	6	6	1	6	57
WBU180-0004	Fish	09/28/2004	Wabash River	05120111180010	14	14	12	5	10	0	6	61
WBU180-0004	Fish	10/14/2004	Wabash River	05120111180010	14	14	12	5	10	0	6	61
WBU190-0004	Fish	06/30/2004	Maria Creek	05120111190010	13	9	8	5	4	0	10	49
WBU200-0001	Fish	08/12/1999	Smalls Creek	05120111200010	6	7	12	9	8	0	6	48
WBU200-0008	Fish	09/15/1999	Wabash River	05120111200030	15	7	13	9	10	0	6	60
WBU200-0015	Fish	09/28/2004	Wabash River	05120111200030	13	15	11	7	10	0	8	64
WBU200-0015	Fish	10/13/2004	Wabash River	05120111200030	13	15	11	7	10	0	8	64
WBU030-0054	Macro	10/18/1991	Otter Creek	05120111030080	14	15	11	6	9	2	10	67
WBU030-0055	Macro	10/18/1991	North Branch Otter Creek	05120111030050	16	15	15	8	9	3	10	76
WBU040-0004	Macro	08/09/1999	Lost Creek	05120111040040	15	6	13	9	5	3	8	59
WBU040-0008	Macro	10/18/1991	Otter Creek	05120111040020	13	15	13	9	9	5	10	74
WBU050-0002	Macro	11/04/1993	Sugar Creek	05120111050040	9	5	11	8	7	2	10	52
WBU050-0003	Macro	11/04/1993	East Little Sugar Creek	05120111050050	14	7	14	4	5	2	10	56
WBU060-0001	Macro	11/10/1993	Honey Creek	05120111060070	13	8	13	6	10	3	6	59
WBU060-0001	Macro	08/31/1999	Honey Creek	05120111060070	10	8	13	3	8	0	6	48
WBU060-0002	Macro	10/07/1992	Unnamed Tributary of Honey Creek	05120111060050	17	13	12	5	11	6	10	74

Table 1 (continued): IDEM QHEI assessment scores within the Middle Wabash - Busseron watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sampling Section	Sample Date	Stream Name	HUC 14	Substrate Score	Stream Cover Score	Channel Score	Riparian Score	Pool Glide Score	Riffle Run Score	Gradient Score	QHEI Total Score
WBU060-0002	Macro	08/31/1999	Unnamed Tributary of Honey Creek	05120111060050	4	12	13	2	5	5	6	47
WBU060-0003	Macro	08/10/1993	Unnamed Tributary of Honey Creek	05120111060050	14	10	13	3	5	1	8	54
WBU060-0003	Macro	08/31/1999	Unnamed Tributary of Honey Creek	05120111060050	4	6	4	2	5	2	8	31
WBU060-0005	Macro	10/07/1992	Honey Creek	05120111060050	14	7	14	5	7	4	8	59
WBU060-0005	Macro	08/31/1999	Honey Creek	05120111060050	12	12	11	4	10	1	8	58
WBU060-0006	Macro	11/10/1993	Honey Creek	05120111060020	9	6	14	4	5	2	10	50
WBU070-0002	Macro	11/04/1993	Clear Creek	05120111070030	13	7	16	5	7	2	10	60
WBU100-0003	Macro	11/10/1993	Prairie Creek	05120111100030	20	19	19	8	11	6	10	93
WBU100-0003	Macro	08/31/1999	Prairie Creek	05120111100030	15	11	16	5	6	3	10	66
WBU100-0004	Macro	11/10/1993	Prairie Creek	05120111100020	16	7	11	4	6	3	6	53
WBU130-0001	Macro	11/09/1993	Turman Creek	05120111130050	14	13	15	6	12	5	4	69
WBU130-0002	Macro	11/09/1993	West Fork Turman Creek	05120111130030	15	13	18	4	5	1	6	62
WBU130-0003	Macro	11/09/1993	Turman Creek	05120111130010	11	7	11	6	5	1	10	51
WBU150-0005	Macro	11/03/1993	Little Turtle Creek	05120111150030	14	6	14	5	5	2	6	52
WBU160-0182	Macro	11/02/1993	Busseron Creek	05120111160130	9	12	19	7	10	4	4	65
WBU160-0183	Macro	11/03/1993	Buck Creek	05120111160100	5	11	11	6	6	5	8	52
WBU160-0184	Macro	11/03/1993	Big Branch	05120111160050	14	11	15	7	8	3	6	64
WBU160-0185	Macro	11/03/1993	Sulphur Creek	05120111160040	9	6	14	4	5	2	8	48
WBU160-0185	Macro	09/14/2004	Sulphur Creek	05120111160040	11	15	13	8	4	0	8	59
WBU190-0001	Macro	11/03/1993	Marsh Creek	05120111190030	5	4	7	3	8	6	6	39
WBU190-0001	Macro	09/01/1999	Marsh Creek	05120111190030	12	5	6	3	4	1	6	37
WBU190-0002	Macro	11/02/1993	Maria Creek	05120111190010	13	8	8	3	5	5	6	48
WBU190-0002	Macro	09/15/2004	Maria Creek	05120111190010	19	15	9	5	7	4	6	65
WBU200-0005	Macro	11/04/1993	Snapp Creek	05120111200020	5	9	11	4	9	5	10	53
WBU200-0005	Macro	09/01/1999	Snapp Creek	05120111200020	5	6	11	5	4	1	10	42
WBU200-0005	Macro	09/15/2004	Snapp Creek	05120111200020	17	8	10	3	8	4	10	60
WBU200-0006	Macro	11/03/1993	Smalls Creek	05120111200010	14	11	8	6	5	4	6	54
WBU200-0006	Macro	09/15/2004	Smalls Creek	05120111200010	14	12	8	3	7	5	10	59
WBU200-0007	Macro	11/04/1993	Smalls Creek	05120111200010	6	6	7	3	5	3	8	38

Table 2: IDEM QHEI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sampling Section	Sample Date	Stream Name	HUC 14	Substrate Score	Stream Cover Score	Channel Score	Riparian Score	Pool Glide Score	Riffle Run Score	Gradient Score	QHEI Total Score
WWL010-0038	Fish	10/17/1996	Bean Blossom Creek	05120202010010	12	14	13	6	5	4	10	64
WWL010-0045	Fish	06/14/2006	Bean Blossom Creek	05120202010030	11	13	15	9	9	0	10	67
WWL020-0009	Fish	10/03/1996	Fish Creek	05120202020140	11	6	11	5	8	0	10	51
WWL020-0010	Fish	10/22/1996	Big Creek	05120202020010	16	18	20	10	8	6	4	82
WWL020-0010	Fish	09/28/2001	Big Creek	05120202020010	15	10	17	10	5	4	4	65
WWL020-0012	Fish	10/03/1996	Little Mill Creek	05120202020020	14	14	16	6	10	3	6	69
WWL020-0054	Fish	06/13/2006	Raccoon Creek	05120202020080	20	18	19	10	10	6	8	91
WWL020-0054	Fish	09/20/2006	Raccoon Creek	05120202020080	13	14	13	10	11	7	8	76
WWL020-0055	Fish	06/07/2006	Fish Creek	05120202020140	12	11	12	6	10	3	6	60
WWL020-0056	Fish	06/19/2006	McCormicks Creek	05120202020030	7	6	18	7	4	1	8	51
WWL020-0057	Fish	10/10/2006	West Fork White River	05120202020010	14	12	13	3	10	0	10	62
WWL020-0058	Fish	06/06/2006	Fish Creek	05120202020140	9	13	12	4	9	0	6	53
WWL030-0004	Fish	07/05/2001	Sloan Ditch	05120202030040	1	13	6	5	4	0	4	33
WWL040-0005	Fish	07/24/2001	Richland Creek	05120202040010	17	8	16	9	5	5	10	70
WWL040-0053	Fish	10/03/1996	Richland Creek	05120202040020	18	10	14	7	10	4	6	69
WWL040-0056	Fish	06/12/2006	Plummer Creek	05120202040090	13	14	19	5	9	5	6	71
WWL040-0056	Fish	07/05/2006	Plummer Creek	05120202040090	13	12	16	6	11	5	6	69
WWL040-0057	Fish	06/07/2006	Richland Creek	05120202040030	13	13	13	5	11	5	6	66
WWL050-0007	Fish	10/21/1996	Weaver Ditch	05120202050090	11	2	5	4	0	0	6	28
WWL050-0010	Fish	08/01/2001	Kane Ditch	05120202050110	12	7	7	4	3	0	4	37
WWL050-0011	Fish	08/21/2001	Unnamed Tributary of First	05120202050070	12	11	19	6	3	3	8	62
WWL050-0036	Fish	10/02/2006	West Fork White River	05120202050090	15	7	14	4	11	4	8	63
WWL050-0038	Fish	06/12/2006	Timmons Ditch	05120202050080	7	8	6	4	6	0	6	37
WWL060-0007	Fish	07/24/2001	Brewer Ditch	05120202060020	0	10	7	5	3	0	4	29
WWL080-0005	Fish	07/31/2001	Eagan Ditch	05120202080060	3	6	7	3	3	0	4	26
WWL080-0006	Fish	08/21/2001	North Fork Prairie Creek	05120202080030	10	4	6	8	3	0	4	35
WWL080-0041	Fish	06/19/2006	Killion Canal	05120202080070	13	13	12	4	10	0	4	56
WWL090-0030	Fish	10/03/2006	West Fork White River	05120202090070	12	11	12	5	11	3	8	62
WWL090-0031	Fish	06/19/2006	Veale Creek	05120202090030	4	14	10	4	6	0	6	44
WWL100-0021	Fish	10/04/2006	White River	05120202100120	12	7	15	5	12	3	6	60
WWL100-0023	Fish	10/03/2006	White River	05120202100030	12	8	12	5	11	1	8	57
WWL010-0009	Macro	10/07/1993	Bean Blossom Creek	05120202010030	12	14	16	7	12	5	8	74

Table 2 (continued): IDEM QHEI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sampling Section	Sample Date	Stream Name	HUC 14	Substrate Score	Stream Cover Score	Channel Score	Riparian Score	Pool Glide Score	Riffle Run Score	Gradient Score	QHEI Total Score
WWL010-0010	Macro	10/29/1992	Jacks Defeat Creek	05120202010100	15	16	15	8	7	5	8	74
WWL010-0011	Macro	10/12/1993	Bear Creek	05120202010030	18	15	18	6	8	5	8	78
WWL010-0012	Macro	10/12/1993	North Fork of Bean Blossom Creek	05120202010020	14	18	18	8	12	6	10	86
WWL010-0012	Macro	07/30/2001	North Fork of Bean Blossom Creek	05120202010020	15	15	20	9	11	3	10	83
WWL010-0013	Macro	10/12/1993	Lick Creek	05120202010030	15	13	18	7	6	5	8	72
WWL010-0045	Macro	07/27/2006	Bean Blossom Creek	05120202010030	9	14	14	8	10	0	10	65
WWL020-0018	Macro	10/23/1992	Raccoon Creek	05120202020070	20	17	17	8	7	7	10	86
WWL020-0019	Macro	10/22/1992	Raccoon Creek	05120202020080	17	19	17	10	9	6	10	88
WWL020-0019	Macro	07/18/2001	Raccoon Creek	05120202020080	20	10	20	10	11	5	10	86
WWL020-0020	Macro	10/27/1992	East Fork Fish Creek	05120202020100	12	17	16	8	7	4	10	74
WWL020-0021	Macro	10/23/1992	Rattlesnake Creek	05120202020050	13	11	15	4	7	3	10	63
WWL020-0022	Macro	10/28/1992	McCormicks Creek	05120202020030	19	11	16	10	7	6	4	73
WWL020-0023	Macro	10/27/1992	East Fork Fish Creek	05120202020100	15	18	18	10	5	3	8	77
WWL020-0024	Macro	10/27/1992	Little Mill Creek	05120202020020	16	14	17	9	7	5	8	76
WWL020-0024	Macro	07/18/2001	Little Mill Creek	05120202020020	20	8	20	8	4	4	10	74
WWL020-0024	Macro	09/13/2004	Little Mill Creek	05120202020020	19	6	19	10	3	0	10	67
WWL020-0025	Macro	10/28/1992	Limestone Creek	05120202020010	16	18	18	8	5	5	4	74
WWL020-0054	Macro	07/19/2006	Raccoon Creek	05120202020080	11	11	14	10	9	4	8	67
WWL020-0055	Macro	07/19/2006	Fish Creek	05120202020140	12	8	12	6	7	0	6	51
WWL020-0056	Macro	07/19/2006	McCormicks Creek	05120202020030	4	5	9	7	3	0	8	36
WWL020-0057	Macro	10/10/2006	West Fork White River	05120202020010	14	12	13	3	10	0	10	62
WWL020-0058	Macro	07/24/2006	Fish Creek	05120202020140	13	7	13	4	10	0	6	53
WWL040-0003	Macro	10/14/1992	Plummer Creek	05120202040090	13	9	17	8	7	5	6	65
WWL040-0007	Macro	10/14/1992	Plummer Creek	05120202040090	11	6	15	6	5	1	6	50
WWL040-0008	Macro	10/15/1992	Plummer Creek	05120202040090	14	15	16	7	7	5	6	70
WWL040-0009	Macro	10/15/1992	Richland Creek	05120202040050	14	8	16	8	7	4	8	65
WWL040-0009	Macro	08/27/1996	Richland Creek	05120202040050	14	13	16	7	10	2	6	68
WWL040-0010	Macro	10/21/1992	Richland Creek	05120202040050	13	12	16	10	9	4	10	74
WWL040-0011	Macro	10/23/1992	Little Richland Creek	05120202040010	11	12	14	5	5	4	4	55
WWL040-0011	Macro	07/18/2001	Little Richland Creek	05120202040010	5	6	13	3	4	3	4	38
WWL040-0056	Macro	07/24/2006	Plummer Creek	05120202040090	12	7	13	8	7	0	6	53
WWL040-0057	Macro	07/24/2006	Richland Creek	05120202040030	13	9	10	4	9	0	6	51

Table 2 (continued): IDEM QHEI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sampling Section	Sample Date	Stream Name	HUC 14	Substrate Score	Stream Cover Score	Channel Score	Riparian Score	Pool Glide Score	Riffle Run Score	Gradient Score	QHEI Total Score
WWL050-0011	Macro	08/21/2001	Unnamed Tributary of First Creek	05120202050070	12	11	19	6	3	3	8	62
WWL050-0036	Macro	10/02/2006	West Fork White River	05120202050090	15	7	14	4	11	4	8	63
WWL050-0038	Macro	07/25/2006	Timmons Ditch	05120202050080	13	5	5	3	6	0	4	36
WWL060-0010	Macro	10/13/1992	Buck Creek	05120202060030	6	5	7	6	9	3	6	42
WWL060-0010	Macro	09/14/2004	Buck Creek	05120202060030	16	15	19	8	8	0	6	72
WWL080-0007	Macro	10/07/1992	Prairie Creek	05120202080070	5	14	6	3	9	0	4	41
WWL080-0041	Macro	07/25/2006	Killion Canal	05120202080070	14	9	10	3	4	2	4	46
WWL090-0009	Macro	10/07/1992	Kessinger Ditch	05120202090060	13	15	19	10	6	0	4	67
WWL090-0010	Macro	10/08/1992	Hawkins Creek	05120202090010	14	15	13	5	7	0	10	64
WWL090-0010	Macro	08/27/1996	Hawkins Creek	05120202090010	8	13	14	4	9	5	10	63
WWL090-0030	Macro	10/03/2006	West Fork White River	05120202090070	12	11	12	5	11	3	8	62
WWL090-0031	Macro	07/25/2006	Veale Creek	05120202090030	12	6	12	4	5	0	10	49
WWL100-0015	Macro	10/07/1992	Plass Ditch	05120202100090	16	7	9	5	3	0	6	46
WWL100-0015	Macro	08/26/1996	Plass Ditch	05120202100090	12	5	6	4	6	2	6	41
WWL100-0021	Macro	10/04/2006	White River	05120202100120	12	7	15	5	12	3	6	60
WWL100-0023	Macro	10/03/2006	White River	05120202100030	12	8	12	5	11	1	8	57

Table 3: IDEM macroinvertebrate IBI assessment scores within the Middle Wabash - Busseron watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sample Date	Stream Name	HUC 14	Sample Type	mIBI Metric Score	Aquatic Life Use
WBU050-0001	10/11/1995	Wabash River	05120111050060	HD	3.6	
WBU030-0054	10/18/1991	Otter Creek	05120111030080	KICK	4.4	
WBU030-0055	10/18/1991	North Branch Otter Creek	05120111030050	KICK	5	
WBU040-0004	08/09/1999	Lost Creek	05120111040040	KICK	2.8	
WBU040-0008	10/18/1991	Otter Creek	05120111040020	KICK	4.8	
WBU050-0002	11/04/1993	Sugar Creek	05120111050040	KICK	2.2	
WBU050-0003	11/04/1993	East Little Sugar Creek	05120111050050	KICK	3.8	
WBU060-0001	11/10/1993	Honey Creek	05120111060070	KICK	1.4	Non-supporting
WBU060-0001	08/31/1999	Honey Creek	05120111060070	KICK	3.8	
WBU060-0002	10/07/1992	Unnamed Tributary of Honey Creek	05120111060050	KICK	3.6	
WBU060-0002	08/31/1999	Unnamed Tributary of Honey Creek	05120111060050	KICK	3.8	
WBU060-0003	08/10/1993	Unnamed Tributary of Honey Creek	05120111060050	KICK	1.4	Non-supporting
WBU060-0003	08/31/1999	Unnamed Tributary of Honey Creek	05120111060050	KICK	2.2	
WBU060-0004	08/10/1993	Unnamed Tributary of Honey Creek	05120111060050	KICK	1	Non-supporting
WBU060-0005	10/07/1992	Honey Creek	05120111060050	KICK	2.4	
WBU060-0005	08/31/1999	Honey Creek	05120111060050	KICK	3.8	
WBU060-0006	11/10/1993	Honey Creek	05120111060020	KICK	2.2	
WBU070-0002	11/04/1993	Clear Creek	05120111070030	KICK	2.2	
WBU100-0003	11/10/1993	Prairie Creek	05120111100030	KICK	4.6	
WBU100-0003	08/31/1999	Prairie Creek	05120111100030	KICK	4.8	
WBU100-0004	11/10/1993	Prairie Creek	05120111100020	KICK	1.4	Non-supporting
WBU130-0001	11/09/1993	Turman Creek	05120111130050	KICK	2	Non-supporting
WBU130-0002	11/09/1993	West Fork Turman Creek	05120111130030	KICK	2.6	
WBU130-0003	11/09/1993	Turman Creek	05120111130010	KICK	2.6	
WBU150-0005	11/03/1993	Little Turtle Creek	05120111150030	KICK	2.2	
WBU160-0182	11/02/1993	Busseron Creek	05120111160130	KICK	3.4	
WBU160-0183	11/03/1993	Buck Creek	05120111160100	KICK	2.2	
WBU160-0184	11/03/1993	Big Branch	05120111160050	KICK	4.4	
WBU160-0185	11/03/1993	Sulphur Creek	05120111160040	KICK	0.8	Non-supporting
WBU190-0001	11/03/1993	Marsh Creek	05120111190030	KICK	2.6	
WBU190-0001	09/01/1999	Marsh Creek	05120111190030	KICK	4.8	
WBU190-0002	11/02/1993	Maria Creek	05120111190010	KICK	4.8	
WBU200-0005	11/04/1993	Snapp Creek	05120111200020	KICK	1.6	Non-supporting
WBU200-0005	09/01/1999	Snapp Creek	05120111200020	KICK	5.4	
WBU200-0006	11/03/1993	Smalls Creek	05120111200010	KICK	3	
WBU200-0007	11/04/1993	Smalls Creek	05120111200010	KICK	3	
WBU160-0185	09/14/2004	Sulphur Creek	05120111160040	MHAB	36	
WBU190-0002	09/15/2004	Maria Creek	05120111190010	MHAB	28	Non-supporting
WBU200-0005	09/15/2004	Snapp Creek	05120111200020	MHAB	34	Non-supporting
WBU200-0006	09/15/2004	Smalls Creek	05120111200010	MHAB	46	

Table 4: IDEM macroinvertebrate IBI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sample Date	Stream Name	HUC 14	Sample Type	mIBI Metric Score	Aquatic Life Use
WWL030-0006	10/11/2001	West Fork White River	05120202030010	HD	5	
WWL010-0009	10/07/1993	Bean Blossom Creek	05120202010030	KICK	4.4	
WWL010-0010	10/29/1992	Jacks Defeat Creek	05120202010100	KICK	3.2	
WWL010-0011	10/12/1993	Bear Creek	05120202010030	KICK	4.8	
WWL010-0012	10/12/1993	North Fork of Bean Blossom Creek	05120202010020	KICK	4.8	
WWL010-0012	07/30/2001	North Fork of Bean Blossom Creek	05120202010020	KICK	5.2	
WWL010-0013	10/12/1993	Lick Creek	05120202010030	KICK	4.8	
WWL020-0018	10/23/1992	Raccoon Creek	05120202020070	KICK	5.8	
WWL020-0019	10/22/1992	Raccoon Creek	05120202020080	KICK	4	
WWL020-0019	07/18/2001	Raccoon Creek	05120202020080	KICK	3.8	
WWL020-0020	10/27/1992	East Fork Fish Creek	05120202020100	KICK	2.2	
WWL020-0021	10/23/1992	Rattlesnake Creek	05120202020050	KICK	2.8	
WWL020-0022	10/28/1992	McCormicks Creek	05120202020030	KICK	2.4	
WWL020-0023	10/27/1992	East Fork Fish Creek	05120202020100	KICK	3.8	
WWL020-0024	10/27/1992	Little Mill Creek	05120202020020	KICK	5.4	
WWL020-0024	07/18/2001	Little Mill Creek	05120202020020	KICK	4.6	
WWL020-0025	10/28/1992	Limestone Creek	05120202020010	KICK	5.2	
WWL040-0003	10/14/1992	Plummer Creek	05120202040090	KICK	4.6	
WWL040-0005	07/03/2001	Richland Creek	05120202040010	KICK	4.2	
WWL040-0007	10/14/1992	Plummer Creek	05120202040090	KICK	2.4	
WWL040-0008	10/15/1992	Plummer Creek	05120202040090	KICK	3.8	
WWL040-0009	10/15/1992	Richland Creek	05120202040050	KICK	5	
WWL040-0009	08/27/1996	Richland Creek	05120202040050	KICK	4	
WWL040-0010	10/21/1992	Richland Creek	05120202040050	KICK	3	
WWL040-0011	10/23/1992	Little Richland Creek	05120202040010	KICK	4.4	
WWL040-0011	07/18/2001	Little Richland Creek	05120202040010	KICK	2.4	
WWL050-0011	08/21/2001	Unnamed Tributary of First Creek	05120202050070	KICK	4.6	
WWL060-0010	10/13/1992	Buck Creek	05120202060030	KICK	4	
WWL080-0007	10/07/1992	Prairie Creek	05120202080070	KICK	1.8	Non-supporting
WWL090-0009	10/07/1992	Kessinger Ditch	05120202090060	KICK	4	
WWL090-0010	10/08/1992	Hawkins Creek	05120202090010	KICK	1.8	Non-supporting
WWL090-0010	08/27/1996	Hawkins Creek	05120202090010	KICK	1.8	Non-supporting

Table 4 (continued): IDEM macroinvertebrate IBI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sample Date	Stream Name	HUC 14	Sample Type	mIBI Metric Score	Aquatic Life Use
WWL100-0015	10/07/1992	Plass Ditch	05120202100090	KICK	4	
WWL100-0015	08/26/1996	Plass Ditch	05120202100090	KICK	3	
WWL010-0045	07/27/2006	Bean Blossom Creek	05120202010030	MHAB	38	
WWL020-0024	09/13/2004	Little Mill Creek	05120202020020	MHAB	40	
WWL020-0054	07/19/2006	Raccoon Creek	05120202020080	MHAB	36	
WWL020-0055	07/19/2006	Fish Creek	05120202020140	MHAB	36	
WWL020-0056	07/19/2006	McCormicks Creek	05120202020030	MHAB	32	Non-supporting
WWL020-0057	10/10/2006	West Fork White River	05120202020010	MHAB	38	
WWL020-0058	07/24/2006	Fish Creek	05120202020140	MHAB	34	Non-supporting
WWL040-0056	07/24/2006	Plummer Creek	05120202040090	MHAB	42	
WWL040-0057	07/24/2006	Richland Creek	05120202040030	MHAB	40	
WWL050-0036	10/02/2006	West Fork White River	05120202050090	MHAB	34	Non-supporting
WWL050-0038	07/25/2006	Timmons Ditch	05120202050080	MHAB	28	Non-supporting
WWL060-0010	09/14/2004	Buck Creek	05120202060030	MHAB	40	
WWL080-0041	07/25/2006	Killion Canal	05120202080070	MHAB	38	
WWL090-0030	10/03/2006	West Fork White River	05120202090070	MHAB	36	
WWL090-0031	07/25/2006	Veale Creek	05120202090030	MHAB	42	
WWL100-0021	10/04/2006	White River	05120202100120	MHAB	38	
WWL100-0023	10/03/2006	White River	05120202100030	MHAB	32	Non-supporting

Table 5: IDEM fish IBI assessment scores within the Middle Wabash - Busseron watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sample Date	Stream Name	HUC 14	Total IBI Score	Aquatic Life Use
WBU020-0023	06/29/2004	Brouillets Creek	05120111020020	54	
WBU030-0056	08/09/1999	Otter Creek	05120111030080	44	
WBU030-0059	06/28/2004	North Branch Otter Creek	05120111030040	40	
WBU030-0060	06/28/2004	North Branch Otter Creek	05120111030050	38	
WBU030-0067	07/29/2004	Spring Creek	05120111030010	38	
WBU030-0067	07/29/2004	Spring Creek	05120111030010	42	
WBU040-0004	08/09/1999	Lost Creek	05120111040040	44	
WBU040-0012	09/15/1999	Wabash River	05120111040050	40	
WBU060-0015	07/06/2004	Honey Creek	05120111060050	48	
WBU090-0006	09/27/2004	Wabash River	05120111090040	38	
WBU090-0006	10/13/2004	Wabash River	05120111090040	42	
WBU150-0006	08/09/1999	Turtle Creek	05120111150030	28	Non-supporting
WBU160-0003	08/09/1999	Busseron Creek	05120111160040	44	
WBU160-0003	09/01/1999	Busseron Creek	05120111160040	24	Non-supporting
WBU160-0216	06/30/2004	Busseron Creek	05120111160010	38	
WBU160-0218	06/30/2004	Busseron Creek West Fork	05120111160030	42	
WBU180-0004	09/28/2004	Wabash River	05120111180010	38	
WBU180-0004	10/14/2004	Wabash River	05120111180010	36	
WBU190-0004	06/30/2004	Maria Creek	05120111190010	30	Non-supporting
WBU200-0001	08/12/1999	Smalls Creek	05120111200010	24	Non-supporting
WBU200-0008	09/15/1999	Wabash River	05120111200030	40	
WBU200-0015	09/28/2004	Wabash River	05120111200030	36	
WBU200-0015	10/13/2004	Wabash River	05120111200030	20	Non-supporting

Table 6: IDEM fish IBI assessment scores within the Lower White watershed. Sites identified by shade are located downstream of the Bear Run permit area.

IDEM Site ID	Sample Date	Stream Name	HUC 14	Total IBI Score	Aquatic Life Use
WWL010-0038	10/17/1996	Bean Blossom Creek	05120202010010	38	
WWL010-0045	06/14/2006	Bean Blossom Creek	05120202010030	46	
WWL020-0009	10/03/1996	Fish Creek	05120202020140	46	
WWL020-0010	10/22/1996	Big Creek	05120202020010	38	
WWL020-0010	09/28/2001	Big Creek	05120202020010	42	
WWL020-0012	10/03/1996	Little Mill Creek	05120202020020	24	Non-supporting
WWL020-0054	06/13/2006	Raccoon Creek	05120202020080	44	
WWL020-0054	09/20/2006	Raccoon Creek	05120202020080	46	
WWL020-0055	06/07/2006	Fish Creek	05120202020140	50	
WWL020-0056	06/19/2006	McCormicks Creek	05120202020030	32	Non-supporting
WWL020-0057	10/10/2006	West Fork White River	05120202020010	32	Non-supporting
WWL020-0058	06/06/2006	Fish Creek	05120202020140	26	Non-supporting
WWL030-0004	07/05/2001	Sloan Ditch	05120202030040	40	
WWL040-0005	07/24/2001	Richland Creek	05120202040010	54	
WWL040-0053	10/03/1996	Richland Creek	05120202040020	36	
WWL040-0056	06/12/2006	Plummer Creek	05120202040090	52	
WWL040-0056	07/05/2006	Plummer Creek	05120202040090	54	
WWL040-0057	06/07/2006	Richland Creek	05120202040030	54	
WWL050-0007	10/21/1996	Weaver Ditch	05120202050090	32	Non-supporting
WWL050-0010	08/01/2001	Kane Ditch	05120202050110	38	
WWL050-0011	08/21/2001	Unnamed Tributary of First Creek	05120202050070	36	
WWL050-0036	10/02/2006	West Fork White River	05120202050090	28	Non-supporting
WWL050-0038	06/12/2006	Timmons Ditch	05120202050080	22	Non-supporting
WWL060-0007	07/24/2001	Brewer Ditch	05120202060020	16	Non-supporting
WWL080-0005	07/31/2001	Eagan Ditch	05120202080060	40	
WWL080-0006	08/21/2001	North Fork Prairie Creek	05120202080030	18	Non-supporting
WWL080-0041	06/19/2006	Killion Canal	05120202080070	46	
WWL090-0030	10/03/2006	West Fork White River	05120202090070	22	Non-supporting
WWL090-0031	06/19/2006	Veale Creek	05120202090030	40	
WWL100-0021	10/04/2006	White River	05120202100120	20	Non-supporting
WWL100-0023	10/03/2006	White River	05120202100030	20	Non-supporting

Wetland Services, Inc. conducted ecological assessments of select surface waters within the permit area and summarized their results in the report Bear Run Bio-Assessment dated July 22, 2010 (updated from previously submitted July 7, 2009 report) which is located in Appendix I.

The following table summarizes a portion of the results conducted to evaluate macroinvertebrate community health, fish community health, aquatic habitat quality, and water quality at the Bear Run (Amendment 4) site. The macroinvertebrate, fish, and aquatic habitat were assessed using EPA's Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish procedures using modifications as recommended by IDEM. Water quality was sampled for total dissolved solids (TDS), pH, total iron, and total manganese.

Bear Run (Amendment4) Bio-Assessment Results				
Sample Point	mIBI/ (INmIBI)	fIBI	RBP	TDS (mg/L)
8NS1	1.6	28	118	139.2
8NS1 (Duplicate)	0.6	-	109	482
18NS13-2	1.2	20	118	342
8NS1-1	1.0	-	105	184.9
8NS1I	1.2	-	94	118.9
9NS-7	1.0	-	119	129.5
25NS1	-	-	83	-
26NS1	(36)	0	113	215
18NS13A	-	-	97	-
15NS1	(30)	0	119	241
4NS29-1	(30)	0	125	68
4NS14-16	(20)	0	129	182
4NS14M-1	-	-	125	-
9NS-6	(36)	36	106	180.6

This table is meant to provide an overall view of the biological quality of the streams as well as the potential sources of impairments. According to the IDEM'S Assessment Branch listing methodology for the Indiana 303(d) impaired waters list, an mIBI score of less than 2.2 or an fIBI score of less than 36 indicates impaired biological communities. Two different protocols were used to assess the macroinvertebrate assemblages, the EPA's Benthic Macroinvertebrate Protocol (mIBI) for the samples collected in 2009 and IDEM Biological Studies Section mIBI (INmIBI). A score of equal to or greater than 36 for the INmIBI is supporting while a score of less than 36 is not supporting.

A recent study at a modern Midwestern coal mine found no significant effects on aquatic life associated with coal mine effluent.<sup>42</sup> The study was conducted at an active underground mine near Georgetown, Illinois which had both open and reclaimed gob/caked slurry coal waste facilities. Fayette Drain is a tributary to the Little Vermilion River, which is known to support populations of the Illinois state-listed endangered Little Spectaclecase mussel, *Villosa lienosa*, and the state-threatened Slippershell mussel, *Alasmodonta viridis*. Various Bioassessment techniques were used to determine if the NPDES permitted discharge was causing measurable impairment to instream communities, particularly to mussels. Based on the data generated from the study, including water chemistry, toxicity testing, benthic macroinvertebrate sampling, and bioaccumulation studies with transplanted freshwater mussels, it was concluded that the discharge from the mine did not have an adverse impact on the biota inhabiting the Fayette Drain. Benthic macroinvertebrate communities were more diverse downstream of the mine site and were dominated by mollusks, whereas the upstream site was dominated by rather tolerant midges (*Chironomidae*). None of the water or sediment samples collected were toxic to standard tests organisms. Furthermore, transplanted mussels did not accumulate significant levels of harmful metals in their tissues compared to upstream transplants after two months exposure, and their Tissue Condition Index (TCI) values were not significantly lower than those placed upstream of the mine site. Water column and sediment toxicity testing may represent snapshots, in that if they indicate toxicity or lack thereof, it is only for the moment at which samples were collected; however, benthic macroinvertebrate surveys and

mussel transplants are not. The data that was collected in the report supports the fact that the coal mine effluent is not a major factor in impairing aquatic communities.

#### Streams and Wetlands (Section 404 Impacts)

Two Section 404 permits have been submitted for the Bear Run Project area. The first Section 404 permit (LRL-2006-1614-gjd) was submitted in October 2006 and approved in January 2007. The second pending Section 404 permit (LRL-2010-193-gjd) was submitted in June 2009. Both permits were submitted to the ACOE and reviewed as Individual Permits which were evaluated under a public comment review.

The Section 404 permit for the Bear Run East Pit (LRL-2006-1614-gjd) covers effects to 4,476.0 acres for surface coal mining and coal preparation facilities. Approved impacts totaled 84,551 linear feet of ephemeral streams, 38,234 linear feet of intermittent streams, and 61.60 acres of wetlands. Compensatory mitigation for impacts within this permit area includes construction or restoration up to 68,995 linear feet of natural design streams with riparian buffers ranging from 25 to 150 feet on each side along with the construction of up to 119.7 acres of palustrine forested wetlands. This permit area covered effects to streams and wetlands and is located across six 14-digit HUC watersheds: Buttermilk Creek, Middle Fork Creek (Sullivan), Brewer Ditch-Black Creek, White River - Pollard Ditch, Black Creek Headwaters, and Singer Ditch (upper) - Hill Ditch.

The Section 404 permit application for the Bear Run (Amendment 4) area (LRL-2010-193-gjd) covers impacts to 2,666.5 acres and is located across five 14-digit HUC watersheds: Buttermilk Creek, Middle Fork Creek (Sullivan), Maria Creek Headwaters, White River - Pollard Ditch, and Brewer Ditch-Black Creek. Delineated impacts total 83,324 linear feet of ephemeral streams, 43,362 linear feet of intermittent streams, and 27.46 acres of wetlands. Compensatory mitigation is provided for these impacts and is included in this narrative.

The Bear Run Project is spread across seven 14-digit HUC watersheds with three draining to Busseron Creek and four draining to the White River. The drainage area for Busseron Creek at its confluence with the Wabash River is approximately 718,412 acres. The Bear Run Project has 1,803.9 acres within this watershed which is only 0.3 percent of the total drainage area of Busseron Creek. The drainage area for the White River at its confluence with the Wabash River is approximately 7,188,900 acres. The Bear Run Project has 5,338.6 acres within this watershed which is only 0.5 percent of the total drainage of the White River. [It is not anticipated that the activities in the proposed Bear Run permit will impact the Busseron Creek and White River watersheds given their large size.](#)

Surface water flow will be affected as a result of these operations. During mining, sedimentation basins will be used to collect storm water at the mine. Storm water will pass through the basins and control the release of storm water by retaining the influent drainage and detaining it for a sufficient amount of time for the required sediment to settle out in the pond and not be part of the discharged effluent water. This added detention time will have two effects. The first will decrease the peak flow from storm events and the second will be an increase in base flow of the receiving stream as the ponds slowly release water after rainfall events. Several permanent incised impoundments will remain after mining is completed. Surface water quantity will be benefited in other ways, as well. These same functions (increased detention times and increased base flows), will be provided by the cast overburden generated in the mining process. The higher porosity and permeability of the cast overburden will allow water to infiltrate and saturate following periods of heavy precipitation and then be released to surrounding streams more slowly. [After reclamation operations are completed, replaced soil infiltration may be temporarily reduced as a result of compaction caused by the heavy equipment used to redistribute the earthen materials. Compaction will be minimized where possible by direct haul-back of soil and mechanical ripping after soil placement.](#) The addition of these surface water impoundments is therefore considered beneficial to the hydrologic balance within and adjacent to the Project area. Because the Bear Run Project area comprises only a small portion of the Busseron Creek and White River watersheds, potential quantity impacts resulting from the proposed operation will be minimal.

Stream and wetland mitigation will take place as quickly as practicable employing the best techniques available to ensure success. Stream mitigation will be constructed utilizing natural channel design. Broad riparian buffers utilizing predominately hard-masted species will be planted adjacent to the stream mitigation enhancing both the habitat and water quality of the onsite, as well as downstream, streams. Wide floodplains will be incorporated adjacent to the stream mitigation, as post-mining land uses allow, which will benefit downstream property owners by providing flood control. Large forested wetlands will be constructed next to some of the streams providing wildlife habitat, water filtration, and flood control. Mitigation areas will be monitored closely by well trained staff. Stream mitigation is a developing science, training will be ongoing and consultants

employed as needed. These mitigation measures will provide great lift to the restored aquatic ecosystem and offset potential longer-term impacts.

### Groundwater

There are no known residential groundwater wells or wellhead protection zones that exist in or within 1,000 feet of the proposed Amendment 4 area. The closest known groundwater user is approximately 2,500 feet west of the amendment area. The stratigraphic interval above and immediately below the lowest coal seam to be mined is not known to contain significant aquifers for potable water use. The underclay and shale permeability averages  $10^{-6}$  to  $10^{-7}$  cm/sec.<sup>8</sup>

Variables affecting soil recharge capacity include permeability of the underlying earth materials, ground slope, amount of vegetative cover, time of year, and evapotranspiration rate. The hydraulic conductivity of Illinoian till in west-central Indiana ranges from  $10^{-8}$  cm/sec. to  $10^{-5}$  cm/sec., with a median of  $10^{-7}$  cm/sec.<sup>45</sup> After mining and reclamation operations are completed, replaced soil infiltration may be slightly reduced as a result of compaction caused by the heavy equipment used to redistribute the earthen materials. Compaction will be minimized where possible by direct haul-back of soil and mechanical ripping after soil placement. Post-mining land management practices such as terracing, moderation of slopes, revegetation, and production of crops are used to improve soil recharge capacity where applicable. Mine spoil generally exhibits higher recharge capacity than undisturbed material. Hydraulic conductivity of spoil in southern Indiana can range from  $10^{-4}$  cm/sec. to  $10^{-6}$  cm/sec.<sup>45</sup>.

SMCRA requires a detailed description of the groundwater monitoring program to be used during the mining and reclamation operations through the release of final bond. This data is evaluated to determine any effects of surface mining activities on the recharge capacity of reclaimed lands and on the quantity and quality of waters systems in and within 1,000 feet of the permit area. To comply with this requirement, groundwater wells are sampled and monitored within and adjacent to the permit to provide representative quality and quantity data for the following parameters: pH, total dissolved solids (TDS), total iron, total manganese, acidity, alkalinity, and water level.

The low permeability of these strata limit the probability that any aquifers that may exist beneath the lowest coal seam to be mined can be affected by operations proposed for the Bear Run Project. This conclusion is based on information obtained from a variety of sources including drilling, review of available water well records, extent of public water supply distribution lines, and talking with the local public. The local lithology above the coal seams to be mined consist of complexly interbedded and discontinuous shale and sandstone lenses exhibiting high clay content. Rocks displaying these characteristics are generally poorly suited for development as reliable sources of potable water.<sup>35</sup>

Areas of previous mining north and east of the Bear Run Mine have resulted in large acreages of saturated spoil and interconnected final pit impoundments. These hydrologic systems developed during the mining process when the overburden was broken up by blasting and removed to recover the coal. The disrupted overburden, or spoil, which was originally solid rock became a heterogeneous mixture of particles ranging in size from clays to boulders. The transition of low permeability consolidated rock to moderately permeable unconsolidated spoil has increased groundwater recharge and storage capacity. These spoil areas absorb considerable recharge from precipitation and slowly release it as base flow to streams and open water bodies. The net effect is an increase in base flow of the receiving streams and a decrease in peak flows.

An evaluation of the hydrologic consequences of surface mining at Bear Run has determined that the operations proposed herein are unlikely to produce reliably measurable permanent changes in the quantity and quality of groundwater existing within the unconsolidated media inside or adjacent to the permit area. The reclaimed area may exhibit a flattened water table because of the higher permeability of spoil material as compared to undisturbed overburden. Groundwater mounding may occur. Groundwater within the spoil interval may exhibit increased mineralization. This effect should be confined to the immediate mined area. The general chemical processes that occur as water moves through spoil are dissolution of calcite, dissolution of dolomite, consumption of oxygen, consumption and release of carbon dioxide, dissolution of pyrite and gypsum, precipitation of goethite (or iron hydroxide), and release of sodium ions by ion exchange (Hall and Davis, 1986).<sup>8</sup>

### Threatened and Endangered Species

As verified by state and federal agencies, there are no sitings or critical habitats known to occur within the permit area.<sup>8</sup> The Bear Run Mine complex is within the range of the federally-endangered Indiana bat (*Myotis sodalis*). The forested riparian corridors present within the permit area are potential habitat for the Indiana bat, but there are no current records of Indiana bats near the project site.<sup>36</sup>

Peabody Midwest Mining, LLC follows conservation measures to minimize the potential take of the Indiana bat by performing tree-clearing outside of the summer reproductive season. The appropriate season to clear trees is from October 1 to March 31. Typically, enough trees are cleared ahead of the active pit to ensure continuous mining through an area until the start of the next tree-clearing window.

The Bear Run Project may potentially impact the summer habitat of the Indiana bat, but reclamation of these forested areas will be comparable in size to pre-mining acreages and will include species suitable for Indiana bat nursery roosts. Species will include exfoliating bark trees such as various hickory, ash, oak, and elm species. Additionally, riparian buffers which will be planted adjacent to all the stream mitigation will provide additional habitat with access to water. The buffers will be comprised primarily of hard-masted hickory and oak species suitable for Indiana bat nursery roosts.

In addition to being in the range of the Indiana bat, the Indiana Natural Heritage Program mapped occurrences of the following state-listed species in the vicinity of the Bear Run Mine. These species are mostly grassland species associated with the Hawthorn Mine, but also a wetland species - American bittern.

Northern harrier (*Circus cyaneus*)  
Henslow's sparrow (*Ammodramus henslowii*)  
American bittern (*Botaurus lentiginosus*)  
Short-eared Owl (*Asio flammeus*)  
American badger (*Taxidea taxus*)

This area is not designated as critical habitat to any listed species, but the Northern harrier, Henslow's sparrow, and Short-eared owl are grassland species and have been known to thrive on mined land. American bittern is a wetland species and the additional wetland mitigation should enhance the habitat for this listed species.

The Indiana Department of Natural Resources have routinely sighted all of the above referenced species on mined sites with the exception the American badger, which was a road kill. The IDNR has concluded that the above listed species are capable of surviving surface coal mining conditions and demonstrated the ability to re-colonize during reclamation activities.

With the area northeast of the Bear Run Mine being heavily mined by both prior to 1977 and post 1977, there is a wide range of habitats. Prior to 1977, there are the numerous spoil piles and pit lakes in the Green-Sullivan State Forest and post 1977, there are large expanses of grasslands at the adjacent Hawthorne Mine. This mix of habitat provides opportunities for both species enrichment and expansion of critical habitats.

### Goose Pond Fish and Wildlife Area

The Goose Pond Fish and Wildlife Area is located approximately 4.0 miles east of the Bear Run Mine. This glacial basin near Linton, Indiana was once an expansive wetland before it was drained early in the last century to support agriculture. Today, efforts are underway to restore wetlands. This is Indiana's largest wetland restoration done under the Natural Resources Conservation Service (NRCS), Wetlands Reserve Program (WRP), United States Department of Agriculture (USDA), and the 7<sup>th</sup> largest in the United States. The restoration covers a little over 8,000 acres in two sections, Goose Pond and Beehunter Marsh. The diverse habitat includes 4,000 acres of shallow open water, 400 acres of bottomland tree plantings, and 1,390 acre of tall and short grass prairies. Restoration began in 2000, with the construction of more than 30 miles of earthen levees and dikes to capture water from precipitation, runoff, and flooding events from the Black Creek - Brewer Ditch and Black Creek Headwaters watersheds. In 2005, the Indiana Department of Natural Resources signed a letter of intent to acquire 8,034 acres for approximately \$8 million and form the Goose Pond Fish and Wildlife Area. The Goose Pond Fish and Wildlife Area will not be a self-sustaining wetland. It will need to be actively managed to keep habitats in early succession stages and to manipulate water levels to optimize habitats for shorebirds and waterfowl.

The wetlands will provide a natural resting site for waterfowl and shorebirds during spring and fall migrations, and a nursery for a variety of waterfowl and other wetland-dependent species. The area is ideally located along the eastern portion of the Mississippi Flyway and is becoming a regular stop for the Greater Sandhill Crane. In 2005, approximately 500 individuals stopped on their spring migration from Tennessee, Georgia, and parts south to breeding grounds in Michigan, Minnesota, Wisconsin, and Ontario. It was reported that in 2009, approximately 4,000 Greater Sandhill Cranes used the Goose Pond Fish and Wildlife Area. This is about a tenth of the entire Great Lakes population.

By restoring the Goose Pond Fish and Wildlife Area to its natural beauty and allowing public access will bring a number of environmental and economic benefits:

- hunters, birders, and naturalists will be attracted to the area bringing their tourism dollars to the community,
- project will restore wetland and adjacent upland habitat for waterfowl, shorebirds, wading birds, and other wetland associated wildlife, and
- area will serve as a filter for water quality and a sponge to slow floodwaters.

A portion of the Bear Run Mine is upstream of the Goose Pond Fish and Wildlife Area. The majority of the mine is buffered from the Goose Pond by previously mined in the Greene-Sullivan State Forest. The open water in Area 5 of the Bear Run (Amendment 4) permit outlets into a tributary of Brewer Ditch which flows along the southern edge of Goose Pond. All disturbed area at the Bear Run Mine would drain to sedimentation ponds to ensure acceptable quality of any drainage from the site. All discharges from the sedimentation ponds would be required to meet the numerical effluent limits for suspended solids, per the NPDES permit. Even though some sedimentation basins will also provide makeup water to the coal preparation plant, there will be no overall impact to downstream water supplies. For example the open water in Area 5 is a sedimentation basin that has an approximate drainage area of 1,775 acres. Downstream of the outfall is a composite drainage area of at least 57,500 acres of watershed upstream of and within the Goose Pond area. Specifically, there is approximately 13,050 acres of watershed, a large part which consists of highly permeable mine spoil and large impoundments created by surface mining (Green-Sullivan State Forest) between the open water in Area 5 of the Bear Run (Amendment 4) permit and the Goose Pond. This large reservoir of surface and groundwater provides a substantial volume of available base flow during drier months and there should be no temporal loss through the process. No negative impacts to the Goose Pond Fish and Wildlife Area will occur from the activities at the Bear Run Mine.

#### Air Quality

The temporary effects to air quality at surface coal mines are mainly due to the fugitive emissions of particulate matter. The major operations producing dust are drilling, blasting, hauling, loading, transporting, and crushing. Basically, dust sources in mines can be categorized as primary sources, actions that generate dust and secondary sources, actions that disperse the dust and carry it from place to place. Effects from dust are not allowed to pass beyond the facility or property line.

The Bear Run Project is regulated by the Indiana Department of Environmental Management Office of Air Quality. The Office of Air Quality is responsible for administering the Clean Air Act permitting, compliance and enforcement programs. There are very stringent procedures for obtaining the proper air permit and the Bear Run Mine has pursued and qualified for the Indiana Source Specific Operating Agreement by SSOA No. 153-26738-00011 permitting agreement which requires that measures will be taken to minimize the effects to air quality. The mine has also submitted an approved Fugitive Dust Control Plan which details Best Management Practices for controlling dust at the mine.

The Bear Run Project will employ a state-of-the-art coal preparation plant facility which will maintain the air quality of the region by removing impurities from the coal before it is burned at electrical generating plants. Mined coal is of variable quality and can include various chemical and mineral matter such as clays, sands, sulphur, and trace elements.

#### Traffic and Transport

Roads in the vicinity of the Bear Run Project consist primarily of county roads with either an asphalt or aggregate surface. They are all two-lane two-way roads with grades that vary from level to rolling. The nearest

Indiana State Road is SR 159 which begins at the Greene County line just east of the town of Pleasantville and ends at Dugger. Pleasantville, a small unincorporated town, is located east of the Bear Run Project. A commercial driveway entrance to the Bear Run complex has been constructed in conformance with Indiana Department of Transportation standards to accommodate service truck and employee traffic. A traffic impact study was completed for the new highway entrance which concluded that the new site access intersection at SR 159 is expected to operate at an acceptable Level of Service (LOS) and no adverse traffic impacts are expected due to the site generated traffic.<sup>37</sup>

Due to the rural location of the Bear Run Project, the increased traffic due to the facility employing approximately 400 skilled workers might have minimal to marginal impact with the local community traffic during the shift changes, but the service truck traffic is expected to be fairly consistent throughout the day with no particular peak arrival or departure pattern. It is expected that the majority of the employees will utilize the existing network of county roads to access Bear Run while service trucks will use SR 159. The new site access is located in the Black Creek - Brewer Ditch 14-digit HUC watershed with SR 159 traveling across the edge of the Black Creek (Ditch) Headwaters before ending in the Buttermilk Creek 14-digit HUC watershed at Dugger.

The majority of coal will be transported via rail on the Indiana Rail Road Company which provides access to regional rail lines and electric utilities. Rail transportation represents an important aspect of a cleaner energy supply chain. Trains are roughly three times more fuel efficient than trucks and can move one ton of freight nearly 450 miles on one gallon of diesel fuel. One coal train can do the work of 500 tri-axle dump trucks, while consuming two-thirds less fuel and produce 70 to 90 percent less emissions.<sup>38</sup>

### Social

The social impacts from the Bear Run Project are expected to be very positive. Sullivan County has a rich heritage of coal mining. The earliest account of mining was mentioned by David Thomas during his travels along the Wabash River in 1816. Though there is evidence that coal mining was present in the county in the first half of the 19<sup>th</sup> century, coal mining as an industry began with the construction of the first railroads through the region. The nearby communities of Pleasantville, east of the Bear Run Project, and Dugger, north of the Project, are surrounded by mining, both pre- and post- SMCRA.

Linton is the largest town closest to the Bear Run Project. This town was officially chartered and named in 1850 and expanded rapidly in the late 1800s as underground mines began operating in the area. As the underground reserves were mined out and the technology evolved to profitably surface mine, the population declined to a stable population of 5,673 in 2009.<sup>39</sup> Mining is such an important industry to Linton, that the mascot of the local high school, Linton-Stockton High School, is the "Miners". This mascot was chosen to honor the industry that contributed to the growth and economics of early Linton.<sup>40</sup>

The operational workforce of the Bear Run Mine is estimated to be approximately 460 skilled workers. Existing skilled workers that transfer from other mines might impact the local demographic and population by choosing to take up residence in the local area and more importantly relocate with their families. It is likely that workers who are single or have young families would be more likely inclined to move. It is unlikely that any significant change in the overall age structure of the local resident population.

It is anticipated that skilled workers that first move to the area may seek short-term accommodations through apartments or rental houses. Those that choose to reside more permanently in the local community may choose to purchase an existing house or build a new house. This may promote development of new subdivisions in the neighboring communities and/or growth in the housing construction and support. Support may include the extension of utilities, installation of septic systems where no sanitary sewer access is available and home improvement services.

### Economic

The economic impact of the Bear Run Project on the local and regional area has been, and is expected to continue to be, very positive and come from three main sources:

- spending in local businesses by employees and their families;
- spending by the Peabody Midwest Mining, LLC on goods and services with local businesses; and
- local property taxes

As production reaches its maximum, the direct employment level will exceed 460 at the mine with annual wages and fringes equaling \$58 million. Additionally, the mine operation will provide significant tax revenue to Sullivan County and the state of Indiana. Many private landowners have received and will continue to receive significant income from the mining operation in the form of royalty payments and/or acquisition proceeds.

A report prepared by Harding, Shymanski and Company, P.S.C. of Evansville, Indiana is provided in Appendix L entitled Economic Impact of Peabody Bear Run Mining, LLC on the Sullivan County Economy. An economic analysis was prepared to encompass both the direct and indirect economic impact of the Bear Run Project on businesses and households in Sullivan County. This estimate was based on projected year 2012 financial data. In performing their analysis, they used the Regional Input-Output Modeling System (RIMS II) as developed by the Bureau of Economic Analysis, U.S. Department of Commerce. The RIMS II measures the economic impact of a business operation by using location-specific multipliers to determine the total output, earnings, and employment generated within a geographic region. From this data, it has been estimated that:

- The Bear Run Project will have total sales of \$376,179,000 with additional sales generated by other businesses as a result of the mine area estimated at \$200,653,879. The total output impact for the Sullivan county (as well as surrounding counties) is estimated at \$576,832,879.;
- The direct spending on local wages and benefits will total \$58,361,000 in 2012. Additional wages and benefits generated by other businesses as a result of the mine are estimated at \$40,858,636 for a total earnings impact of \$99,219,536.;
- The company will employ 462 people in Sullivan County. Additional employment generated by other businesses a result of the mine's impact on the local economy is estimated at 768 jobs. The total employment impact for the area is estimated at 1,230 jobs.; and
- Peabody Midwest Mining, LLC will pay local property taxes totaling \$3,769,000.

In terms of cumulative economic impacts, the Bear Run Project will contribute to the basic electricity production in Indiana and surrounding states. Coal is Indiana's major energy source by generating 95 percent of its electricity. A study prepared for the Center for Coal Technology Research Energy Center at Discovery Park (Purdue University) entitled Estimating the State and Regional Benefits of the Mining and Use of Illinois Basin Coals estimated the economic impact that coal has on the individual states of Illinois, Indiana, and Kentucky in the Illinois Basin for the year 2007 using RIMS II multipliers. In 2007, Indiana mined 34.8 million tons of coal. Of this amount:

- 2.95 million tons were exported out of the state at an average price of \$28.79/ton for a total export value of \$84.8 million. By applying the Indiana coal mining multiplier, the total amount of economic activity arising from the mining of this coal was \$166 million.;
- 2.0 million tons were used by Indiana industry either to generate or co-generate electricity. The total estimated economic activity from mining this coal was \$347 million.;
- 29.4 million tons were converted into electricity in Indiana, resulting in the generation of an estimated 70 billion kwh with sales of \$4,541 million. The estimated economic activity from mining this coal was \$6,766 million.;
- The total estimated amount of economic activity arising from these three uses of Indiana coal for Indiana is approximately \$7,279 million, or 3 percent of Indiana Gross State Product.<sup>41</sup>

Peabody Energy is investing approximately \$400 million in capital to bring the Bear Run Project up to capacity and should contribute approximately \$140 million in regional economic benefits. After the press release of the development of the Bear Run Mine, Indiana Governor Mitch Daniels made the following statement, "Coal is the key to American energy independence and to the affordable power in which Indiana's future prosperity depends. This is great job news in the near and long term."

### Connected Activities

The Bear Run Mine has no connection to other activities including the Duke Energy Edwardsport Generating Station or any other utilities. The Bear Run Project is being developed to supply long-term contracts to area utilities. Existing major coal supply agreements are with Duke Energy and Hoosier Energy. Duke Energy has the prerogative of directing coal shipments to any of its local generating facilities. The Indiana Rail Road constructed a spur to the Bear Run loading facility for which impacts and mitigation of approximately 2 acres of wetlands were authorized by separate permits.

### Existing Mitigation and Monitoring Sites

Peabody Midwest Mining, LLC is fully capable of and committed to constructing successful stream and wetland mitigation. All levels of management and field personnel are informed of the importance of successful stream and wetland mitigation and all of Peabody's active Midwest sites. [Experience of trained company personnel is included in the credentials section of this application; those listed will continue receiving the latest training available.](#) Additional personnel are also scheduled for training. Peabody's regional and corporate engineering and environmental staffs are dedicated to providing technical support to each of its mining operations.

Currently stream and wetland mitigation is being completed on several Peabody mine sites in the Midwest including Wildcat Hills Mine - Cottage Grove Pit, Wildcat Hills Mine - Eagle Valley Pit, Francisco Mine, Farmersburg Mine, Viking Mine - Corning Pit, Viking Mine - Knox Pit, Miller Creek Mine - Jenlin Pit, Air Quality Mine - Hart Street South Portal, Somerville South Mine, Somerville Central Mine, and Wild Boar Mine. Stream construction is in various stages within these sites with some fully constructed and being monitored while others are fully constructed but not formally monitored until the riparian buffers are planted. Other sites are having channels being constructed and structures installed. Some are in the floodplain grading and final channel design stage.

Peabody Midwest Mining, LLC utilizes the latest technology in GPS surveying to assist the stream and wetland construction efforts and has added additional dozer-mounted units to its reclamation fleets to further enhance the final reclamation product. This equipment is considered essential to successful mitigation. Annual mitigation field work is completed primarily during the late spring to early fall time period when soil conditions are driest. Final floodplain grading, channel construction, and installations of structures are targeted for completion during this time to allow for proper revegetation during the appropriate fall seeding period. In addition, Peabody has found it is best to temporarily divert surface runoff entering a new stream perpendicularly, in order to allow sufficient establishment of vegetation on the banks before returning normal flows. Temporary diversions are removed when adequate vegetative stability is achieved. Also, stabilization of new channels with erosion control blankets in critical areas is very important. Use of appropriate willow cuttings within the stream channels has proven to be very effective in aiding stabilization as well as providing an early shading benefit to streams. While initial structure placement is important in critical areas, it is also important to re-evaluate structure needs following several precipitation events. Initial erosion control seems to be the biggest initial challenge. Intense precipitation during construction or prior to vegetation establishment is problematic for any construction project. Repairs and maintenance are made as needed.

Peabody is committed to continue to develop Best Practices for stream and wetland mitigation and meet or exceed the requirements in all of its 404 permits. Much progress is being made in terms of on ground success at all locations. Some noted examples of successes that have been viewed and evaluated by government agency and independent consultant experts include ephemeral stream mitigation at the Viking Mine-Knox Pit, mitigation of West Fork Busseron Creek at the Farmersburg Mine. Much is being learned from all of the sites and best practices developed accordingly. Plans have not been made final, but several of Peabody's Indiana sites will be made part of the Office of Surface Mining (OSM) Stream Design Workshop to be held in Indiana and Illinois.

In terms of wetland mitigation, Peabody has completed successful mitigation both on-site and off-site. More history is available for off-site areas as the opportunity is available to complete these earlier. Noted examples of wetland mitigation success can be found at the Wildcat Hills Mine-Eagle Valley Pit and Cottage Grove Pit in Illinois, as well as, the Francisco and Jenlin sites in Indiana. Portions of the off-site mitigation in Illinois has met the final requirements and been released from further monitoring. Other wetland sites are in various stages of construction at several sites. It should be noted that wetland mitigation at all sites is being completed as hardwood forested wetlands, replacing many lower quality wetlands. Peabody has very extensive success in reforestation on mined lands from both a survival and growth standpoint. This vast experience will drive success in both the forested wetlands and stream riparian corridors.

West Fork Busseron Creek was reviewed in the field by Jeff Barry, PhD of ENVIRON International Corporation, in his technical memorandum concerning the restoration of Big Creek at the Wild Boar Mine and stream channel design recommendations. Based on Dr. Barry's observations, he states that, "it is clear that the "natural stream channel" design method was a success. The most significant observation was that in 2008 two extreme rainfall events occurred, both approximately equal to a 100-year event, flowing water across the floodplain was over 6 feet deep yet there is very little evidence of floodplain, bank, or channel erosion. This observation suggests a very dynamically stable stream network."<sup>32</sup>

George Anthanasakes, PE, a Principal of the Ecosystem Restoration Services for Stantec, Inc., in Louisville, Kentucky, visited several Peabody Midwest Mining, LLC stream mitigation sites in June of 2009. Mitigation sites at Somerville Central Mine, Viking Mine - Knox Pit and Corning Pit, and Farmersburg Mine were visited to get his professional opinion on how the mitigation is developing and any areas that need improvement. George who is the program manager of RIVERMorph and holds Bachelor's and Master's in Civil Engineering degrees from the University of Louisville. For over a decade, Mr. Anthanasakes has served as the project manager and/or design engineer on numerous stream restoration and assessment projects incorporating natural channel design principals. George was pleased with the sites and thought the company is doing some great work. He was amazed by the natural migration of willows along the stream banks along the mitigated West Fork Busseron Creek at the Farmersburg Mine. The willows provided bank stability, shading, and habitat.

George provided several suggestions for improvement and suggested the mitigation could benefit from the development of regional curves for the mined sites, to help with sizing the channels. David Bidelsbach, PE, a design engineer working for Stantec, Inc., in Raleigh, North Carolina came to Indiana and developed a mini-regional curve for Indiana, which is provided in Appendix M. Mr. Bidelsbach has a master's degree in biological and agricultural engineering from The Pennsylvania State University and is currently working on a PhD in the Department of Biological and Agricultural Engineering at North Carolina State University. He has worked with the North Carolina Stream Restoration Institute at North Carolina State University, teaching educational courses in stream design.

- C. Maps (8 1/2" x 11") with project site clearly identified.
  - 1. County road map
  - 2. USGS quadrangle map
  - 3. NWI maps, if available
  - 4. FEMA floodplain maps, if available

See Map A in Appendix A for a portion of the Dugger and Bucktown 7.5 minute quadrangle maps with the permit areas clearly located. Map B in Appendix A shows the location of the existing streams and wetlands.

- D. Aerial Photography, if available
- E. USDA/NRCS County Soil survey sheet for site

See Map WS in Appendix A for the soils map.

- F. Photographs of the site with a corresponding photo orientation map

See Map B in Appendix A for the location of the assessment points, Appendix B for stream photographs, Appendix C for wetland photographs, and Appendix D for open water photographs.

- G. Identification of responsible parties: Provide names, titles, addresses, and phone numbers for the following:
  - 1. Applicant(s)

Peabody Midwest Mining, LLC f/k/a Black Beauty Coal Company, LLC  
7100 Eagle Crest Boulevard, Suite 100  
Evansville, Indiana 47715

- 2. Contact person(s) if applicant is a company

Bryce West  
Authorized Representative  
Telephone: 812-434-8500

3. Consultant or agent preparing permit application

Not Applicable

4. Consultant or agent responsible for supervising or providing biological monitoring

Not Applicable

5. Property owner(s)

See Block 24 in Appendix G

## II. Proposed Mitigation Site:

- A. Briefly discuss the overall mitigation concept and purpose, and then provide the same information as requested for the **Proposed Impact Site** (listed above) following the same format. The data point taken on the proposed mitigation site should remain consistent with the permanent photo stations identified in the subsequent monitoring reports.

### Wetlands

The jurisdictional wetlands that are disturbed by mining or related activities will be greatly enhanced and mitigated on-site. Those wetlands not presently classified as PFO will be mitigated with PFO bottomland hardwood wetlands. Wetlands presently classified as PFO will be mitigated with PFO bottomland hardwood wetlands regardless of the existing dominant tree type (i.e. existing PFO wetlands with dominant soft-mast tree species). Wetland mitigation will be located on property controlled by Peabody Midwest Mining, LLC. If any modification to the proposed mitigation language or mitigation locations is necessary, a request will be submitted to the ACOE for review and prior approval. Wetland species will consist of those listed in the planting plan in Section 3 under the Wetland Seeding and Planting Stock Summary table. Tree species will be managed for predominately hard-mast producing species. Flat topography will be constructed which will provide a desirable hydrologic environment for the creation of forested wetlands. The hydrology will be enhanced by stream mitigation designs which will include a wide floodplain at the bankfull depth in the area of the wetland mitigation. In Appendix A, see Map C for the proposed location of the mitigated wetlands and Map D6 for a typical plan view and cross-section.

### Streams

The proposed mitigation will consist of stream creation with enhancements which will include: the creation of floodplains as land-use and topography allow; constructing appropriately designed channels; installation of in-stream structures that will allow for aquatic habitat, as well as provide erosion and grade control; and planting riparian vegetation to provide stability along the banks. Such improvements are intended to promote a positive biological response within the stream's aquatic communities.

As streams are being mined through, temporary diversion ditches will be built to direct the water around the pit facilitating the mining process. The use of diversion ditches allows the streams to be put back in planned locations where flood plain areas can be widened where necessary. The general topography and geomorphology will be similar to the pre-mining conditions, but will have some swell due to the handling of disturbed overburden material. The regraded watersheds will generally mimic the pre-mining conditions, and replaced streams will be designed and constructed so that pre-mining connectivity is maintained. Streams will be constructed in valleys and not along hillsides. Streams will be mitigated with a naturally designed channel that will provide a lift over the present conditions. This lift will be comprised of, but not limited to, an enhanced riparian buffer, natural channel configuration, reduced entrenchment, and engineered structures.

If any modification to the proposed mitigation language or mitigation locations is needed, a request will be submitted to the ACOE for review and prior approval. Riparian habitat buffers will be established for the natural design streams and will be comprised of a combination of plantings as shown in the table listed in the Planting Plan in Section 3 under Forest/Wildlife Habitat for Stream Buffer Areas. In Appendix A, see Map C for the proposed location of the mitigated streams and Maps D1 to D5 for generalized plan and profile views.

As additional enhancement, soil depths may be increased when constructing the mitigated streams. Required soil depth varies from 1-4 feet; however, actual replaced depths typically vary from 4-6 feet. Increased soil depths in formerly thin or devoid areas enhances many important terrestrial ecological functions including the

regulation and partition of water flow, the storage and cycling of nutrients, filtering and buffering of contaminants and nutrients, and the degradation of organic and inorganic materials. The following mitigation plan will not only enhance the quality of the immediate drainage area but also improve the quality of the receiving waters.

#### Buttermilk Creek Stream and Wetland Restoration

In addition to the on-site mitigation proposed above, off-site advance mitigation is proposed to compensate for temporal impacts created by mining. The site is located along Buttermilk Creek northwest of the permit area on property owned by American Land Holdings of Indiana LLC, a subsidiary of Peabody Energy. The property is west of Dugger and is bounded on the north by SR 54 and CR 200 East and CR 275 East. A comprehensive plan with mitigation details is provided in Appendix J.

- B. Indicate who presently owns the proposed mitigation site. Availability of property must be clearly defined prior to final review. All easements and/or encroachments located on the proposed mitigation site must be identified. The applicant should own the mitigation site. The mitigation site should not be constructed on public lands unless the landowner is the responsible party.

Peabody Midwest Mining, LLC presently controls the proposed mitigation sites for the wetlands and streams. Controlled denotes that Peabody Energy or a subsidiary either owns the property or has a legal document with a property owner to enter the property and surface mine the reserve. Documents describing the legal rights to enter and engage in surface mining activities are comprised of deeds and leasehold instruments. These documents are recorded at the appropriate county courthouse offices and retained on file. The mitigated streams will traverse across the permit area collecting surface runoff and transporting it to the receiving watersheds of Buttermilk Creek, Middle Fork Creek, Maria Creek, Pollard Ditch, or Brewer Ditch.

- C. Indicated expected ownership of the mitigation site following completion of the mitigation project. The responsible party for long-term management and protection of the site must be identified. A signed management agreement must be submitted if an entity other than the permittee will assume management responsibilities following completion of the mitigation project.

The property control of the mitigation sites for the permit area is not expected to change until final SMCRA bond release is approved. During acquisition procedures, property may be bought from the original owner or leased. On certain properties that are bought, a Right of First Refusal (ROFR) agreement may be made where the original property owner has the first right to buy back the property if the company decides to sell it. Peabody Energy or a subsidiary owns the majority of the permit area with only three parcels that have a ROFR agreement associated with them. There are ten lease properties in the permit area. Please see Map F in Appendix A which shows hatches for the properties not owned at this time. Portions of the permit area will revert back to the original owner and any future landowner will be subject to the conditions and requirements of Section 404 of the Clean Water Act for any impacts to the streams and wetlands and to any deed restrictions placed on the mitigation locations.

Please see Map F in Appendix A which shows the mitigation and the property tracts not owned at this time and which cannot legally be encumbered by a deed restriction due to the property being leased to a Peabody subsidiary or the previous landowner having signed an agreement with the company for ROFR. While deed restrictions can only be placed on properties owned by a Peabody subsidiary, mitigation has been located to maximize protection opportunity. Portions of the permit area that revert back to the original owner or are owned by any future landowner not affiliated with a Peabody subsidiary will be subject to the conditions and requirements of Section 404 of the Clean Water Act for any impacts to the streams and wetlands and to any deed restrictions placed on the mitigation locations. Where deed restrictions can be made, they will be placed prior to and in conjunction with approval to cease monitoring. A copy of the deed restrictive instrument is provided in Appendix N.

## Section 2: Goals and Objectives of the Proposed Mitigation

I. Using the information gathered under Section 1: Baseline Information, conduct a resource comparison of the impact site and the proposed mitigation site. This documentation should follow the format outlined below:

A. Functions and Values

1. Narrative profile of existing functions and values

- a. Site-specific discussion of the proposed impact site's functions and values
- b. Watershed/Landscape Context (What functions/values does the aquatic resource at the impact site provide within the surrounding landscape and watershed? And in what context?)
- c. If applicable, discuss the proposed project's impact on known functional impairments within the watershed (e.g. state listed CWA Section 303(d) impaired waterbodies).
- d. Identify any rare or unique areas; including any know cultural resources, habitat designation and ecological types.

The existing functions and values of the streams within the permit area vary widely from stable (natural streams in wooded areas) to degraded (reclaimed permanent diversions in open areas). The streams within the natural wooded area have the greatest function and value in regards to the physical, biological, and chemical aspects while the streams in the reclaimed area could be considered to have the least by only functioning in regards to the physical aspect. All streams from fully functional to functional impaired provide some type of surface water storage and conveyance. All of the existing ephemeral reclaimed streams were not designed, but that occur from erosional features in response to precipitation events. Other types of physical stream functions in addition to surface water storage (either short term or long term) are subsurface water storage, variations in the energy gradient of the stream (riffles, pools, glides, runs, and step pools), sediment transport, and physical structures such as riffles and root wads that control velocity and provide spawning habitat and continued stream evolution. As the landscape setting changes from reclaimed to natural, the benefits from biological and chemical functions and values increase. The riparian buffer of the stream provides biological functions in the form of habitat; biomass which promotes organism growth, supplies nutrients, and maintains complex animal communities. Chemical functions provided by the stream riparian buffer are improving water quality and maintaining numerous nutrient cycles. In areas where the buffer has been removed for agricultural practices or logging, the water quality degrades significantly with excess sedimentation and decrease in wildlife habitat diversity. Although surface mining may temporarily remove buffers along the stream, compensatory mitigation replaces buffers along the natural design streams. The downstream water quality does not experience significant degradation due to excess sedimentation as it is controlled through NPDES requirements. The riparian buffer traps, retains, and removes dissolved and particulate matter from surface and overland flows into the streams.

The aquatic organisms resident to the site are determined by a combination of factors such as non-point source pollution including row crop agriculture and the small drainage areas. The most widespread stressors observed across the country are nitrogen, phosphorus, streambed sediments, and riparian disturbance. Sediment loading, another non-point source pollution linked to agriculture, can cause low dissolved oxygen levels which may explain the presence of blood worms and left-handed snails which differ from right-handed snails in their ability to live in low dissolved oxygen environments.

The families and genera that were to be dominate in the permit area are mosquitoes, mayflies, black flies, water louse and various types of midges from the bloodworm family. These particular genera typically occur in lentic habitats. Only discontinuous pools were present in the streams creating a more "lentic" habitat in the streams and after a rain event, the streams became continuous and a more "lotic" environment.

Invertebrates have different strategies for surviving in a drying stream. They can avoid desiccation by burrowing into saturated substrates, migrating to receding pools, having life history adaptations, or by having desiccation resistant forms, (Rosalie B. del Rosario and Vincent H. Resh 2000). The family Culicidae, some genera, (e.g. Aedes), have an incubation and hatching period that is highly variable. Embryonic development is 2-4 days after inundation and at the same time the eggs can withstand desiccation for at least one year, (R.W. Merritt, K.W. Cummins, M.B. Berg 2008). This allows for an ability to survive in periods of "drying" of the intermittent streams that occur in the permit area. Mayflies because of their adult winged stage and propensity for drift as nymphs, are often among the first macro invertebrates to colonize virgin habitats. Mayflies are also a major component of invertebrate drift in running waters and occurred throughout the streams sampled after a rain event.

The presence and abundance of stream fishes is strongly related to the physical and chemical characteristics of a stream. The number of minnow, darter, sculpin, and madtom species increase with higher quality streams.

Minnows are long-lived and sensitive to degradation. Simple lithophilic species are indicators of the degree of sedimentation and contamination. They require clean gravel or cobble to spawn and cannot reproduce in streams with high levels of sedimentation, contaminated, unstable, or frequently disturbed substrates.

The families and genera found to be present in the permit area were bluegill, largemouth bass, stonerollers, and several different species of minnows and darters. Some of the more dominant species sampled from the streams prefer shallow, riffle areas with gravel and sand substrates. Silverjaw minnows are found almost exclusively in areas with sand substrates while the orangethroat darter inhabits shallow gravel riffles. The bluegill and largemouth bass that are found in these stream systems primarily feed on macro-invertebrates and smaller fish species. There were only three sample sites found to support fish populations.

The existing functions and values for the wetlands within the permit area vary widely from fairly good (large natural PFO wetlands) to poor (isolated reclaimed wetlands in the reclaimed area). All the wetlands provide three broad types of function: habitat, water quality, and hydrologic. Wetlands provide habitat in the form of shelter, water, and food for plants, insects, amphibians, reptiles, fish, shellfish, birds, and mammals along with areas for breeding and nurseries. Wetlands provide water quality in the form of trapping sediment, controlling pollution, and supporting biochemical processes. Finally, wetlands support a hydrological function by recharging groundwater, reducing flow velocities of surface runoff, and influencing atmospheric processes. The wetlands in the Bear Run Mine (Amendment 4) permit perform the majority of these functions, but the size of the wetland dictates how large scale and effective the functions can be. For example, the small PUB wetlands within the reclaimed areas provide a greater habitat function than a water quality or hydrologic function, while the larger natural wetlands provide for all three.

Of the wetlands on site, those along the unnamed tributary to Pollard Ditch in Area 3, see Map B6 in Appendix A and delineations for Wetlands 8NW4, 8NW5, and 8NW7 in Appendix C, contain the most function and value. These functions and values are described as follows. The function of surface water storage helps prevent flooding by distributing and absorbing excess water. This will allow water to slowly release to surface drainages, soak into the ground, or evaporate. Temporary storage can help reduce peak water flows after a storm by slowing water movement into tributary streams which allows potential floodwaters to reach the receiving streams over a longer period of time, thus reducing flooding impacts. Water quality is also improved by absorbing nutrients, pesticides, and bacteria from surface waters as they soak in or are broken down by plants, animals, and chemical processes within the wetland. Wetlands promote the decomposition of organic matter, thus incorporating nutrients back into the food chain. By filtering out sediments and particles that are suspended in the surface waters, these wetlands help prevent rivers, lakes, and other streams from being affected by downstream sediment loading. This improves water quality and extends the life of water bodies by reducing sedimentation rates. These wetlands provide breeding, nesting, and feeding habitat for waterfowl, birds, fish, and other wildlife, and provide values including flood control, water quality improvement, and potential hunting and trapping opportunities.

The value of the remaining streams and wetlands depends on the benefit each provides to the environment and the community, although this may be regarded differently from one person or community to the next. Certain groups may value the ecological importance of wetlands while others may see the wetlands as having social or economic importance. Ecological importance includes pollution control, flood control, and wildlife habitat. Social importance of wetlands includes the benefit they provide to hunters, fisherman, or as outdoor recreation like bird watching. Economic importance may include timber production. The greatest value of the existing streams and wetlands within the Bear Run Mine (Amendment 4) permit is the wildlife habitat they provide.

The watersheds of the proposed permit have, are, and will be impacted by mining and agricultural activities for the foreseeable future. The topography of the land is such that agriculture will be the predominate land use where topography and drainage control are suitable. Both of these activities have been major factors on water quality in the watershed areas.

As discussed in *Section 1.1.B.3.b* on page 3, which explains the general benefits of coal mine reclamation at this site, erosion produces sediment, which negatively impacts and impairs the water quality of the project area's streams and wetlands as well as the receiving waters. During mining temporary sediment basins will be used to minimize sediment and water quality impacts to the receiving waters. Subsequent to reclamation, the mitigation will provide an enormous lift over the present conditions. This lift will be comprised of, but not limited to an enhanced riparian buffers placed along the length of the mitigated stream, natural design, engineered structure placement, and reduced entrenchment.

The Indiana Surface Mining Control and Reclamation Act (SMCRA) requires that any archaeological and historical issues be cleared by the IDNR in consultation with the Indiana State Historic Preservation officer. The cultural resources reviews for the permit area covered by IDNR permit S-00256 and approved amendments. Area 2, Area 3, Area 4, and Area 5 (covered by IDNR permit S-00256-4) are pending clearance and must be cleared before approval of the SMCRA application. Area 1 has already received clearance from the IDNR in consultation with the Indiana State Historic Preservation officer.

Indiana SMCRA requires that the state and federal fish and wildlife agencies must be contacted for their comments on the proposed permit application before approval. The state fish and wildlife agency must make a finding that the mining operation will not affect the continued existence of endangered or threatened species or result in destruction or adverse modifications of their critical habitats. This process is completed during the SMCRA permitting process.

2. Predicted future functions and values
  - a. Site-specific discussion of the predicted future functions and values of the mitigation site.
  - b. Watershed/Landscape Context: What functions/values would the proposed aquatic resource provide within the surrounding landscape and watershed? And in what context?)

The predicted future of the mitigation sites will be stable and self-sustaining. This is the ultimate goal for any mitigation. If something is altered, it should be restored to a condition that is just as good as or even better than it was initially. The future function of the natural design mitigated streams will be to convey surface water and provide functional habitat and support for terrestrial and aquatic animals. Habitat will be improved for the aquatic species by incorporating log vanes, utilizing riffles and pools and incorporating root wads in construction. Engineered structures which contribute to channel stability also provide habitat and refuge. Surface coal mining is not a long-term or permanent impact on jurisdictional waters or land function and productivity. Impacts to land and water resources are mitigated by planned reclamation that results in a sustainable resource.

Surface coal mining in the Illinois Basin naturally enhances drainage patterns by lowering runoff velocity that significantly reduces erosion and transport of suspended solids, particularly compared to typical runoff in areas with an agricultural land use, and extends the duration of runoff which improves water quality. Suspended solids loadings smother aquatic communities which destroy reproductive habitat. Site reclamation produces topographic relief consistent with the local area and incorporates many erosion control methods as exhibited on other reclaimed surface-mined areas. Reclaimed sites have increased species and habitat diversity thereby enhancing the ecological function of the area provided by additional wetlands and open water.

- B. Function losses on Proposed Project Site verses Functional Gains on Proposed Mitigation Site
  1. Methodology of measurement
  2. Watershed Consequences (Although not required, providing information on a successful mitigation project or lessons learned on an unsuccessful project in the same watershed would be beneficial.)
  3. Debits/Credits
    - a. Acreage/Linear Feet (in addition to functional units)
    - b. Functional capacity (e.g., HGM Functional Capacity Units or Ecological Integrity Units)

### Wetland Mitigation

Peabody Midwest Mining, LLC proposes a wetland mitigation plan that replaces all jurisdictional wetlands disturbed by mining activity at the ratios in the table below. The mitigated wetlands will be measured for success by following the 1987 Corps of Engineers Wetland Delineation Manual<sup>4</sup> along with the Midwest Regional Supplement<sup>28</sup>.

Wetland Mitigation				
Setting	Wetland Type	Impacted Acreage	Mitigation Rate	Mitigation Acreage
		(acre)		(acre)
Natural	PFO	8.45	3:1	25.35
	PSS	0.53	2:1	1.06
	PEM	0.96	2:1	1.92

	PUB	0.53	2:1	1.06
Reclaimed	PFO	1.96	2:1	3.92
	PSS	0.27	2:1	0.54
	PEM	9.89	1.5:1	14.84
	PUB	4.86	1.5:1	7.29
Total Wetland Mitigation				56.00 (PFO1A)

A total of 56.00 acres of temporarily flooded broad-leaved deciduous forested wetlands (PFO1A) will be the mitigation acreage for all jurisdictional wetlands that are disturbed by mining activity. Wetland hydrology in the constructed PFO area(s) will be driven by connection with adjacent stream hydrology that supports water inflow, retention and outflow from the system and by groundwater recharge. The wetlands will be greatly enhanced by planting red and white oak, hickory, and pecan trees for wildlife; and other species as found in the wetland planting stock table. Construction of stream terraces between stream banks and wetlands will facilitate the development of necessary hydrology by ensuring that: 1) adequate runoff from upland areas will inundate the wetland following precipitation events and 2) retention of above bankfull flows from adjacent streams; allowing hydric soils to develop.

#### Stream Mitigation

Peabody Midwest Mining, LLC proposes a stream mitigation plan that restores all jurisdictional streams disturbed by mining and related activity at the ratios and lengths in the table below.

Stream Mitigation				
Setting	Flow Regime	Impacted Length	Mitigation Rate	Mitigation Length
		(feet)		(feet)
Natural	Ephemeral	81,033	0.5:1	40,517
	Intermittent	42,590	1:1	42,590
Reclaimed	Ephemeral	2,291	0.5:1	1,146
	Intermittent	772	1:1	772
Total Natural Design Ephemeral Stream Mitigation				41,663
Total Natural Design Intermittent Stream Mitigation				43,362

All streams will be mitigated in length at the rates found on the above table and have a riparian buffers planted on each side of the mitigated stream. A minimum 50-foot riparian buffer will be planted on each side of the natural design ephemeral stream mitigation and a minimum 100-foot riparian buffer will be planted on each side of the natural design intermittent stream mitigation.

Enhancements will consist of, but not be limited to, broad hardwood riparian corridors with predominately hard-mast producing species, persimmon species for wildlife, expanded sinuosity, use of engineered structures to stabilize the streams, reduced entrenchment, replacement of any Rosgen<sup>3</sup> "G" or "F" channels, and adding a floodplain as post-mining land uses allow.

Rosgen<sup>3</sup> level II and III characteristics have been measured in the field for the existing streams. The stream assessment sheets are located in Appendix B with the locations shown on Map B in Appendix A. These classifications describe the existing geometry of the stream and provide a basis for the natural stream replacement design. Approximately 46 percent of all the existing streams have an impaired Rosgen "G" or "F" classification. These entrenched gully channels, which have incised enough to abandon their former floodplains, are dominated by degrading step/pool systems and will be replaced with stream mitigation that is approximately 80 percent, Rosgen "C" channel type, and approximately 20 percent, Rosgen "B" or "A" channel type depending on the slope.

All natural design streams will be constructed with a riparian buffer on either side of the stream, but only the Rosgen "C" channels will have an enhanced floodplain constructed. The "B" and "A" type streams by definition are found in gently sloping to steep narrow valleys with slopes ranging from 2 - 10% slope, while "C" channel

types are found in well developed floodplains with a channel slope of 2% or less. "B" and "A" type streams do not have floodplains associated with them, but a "C" type stream does. The entrenchment ratio range for each of the stream types indicates the degree of vertical containment of the stream. The term "enhanced floodplain" is used to indicate that the post-mine floodplain width will be increased over the pre-mine floodplain width. A critical element for successful "C" channel type stream mitigation is access to its floodplain and floodplain storage.

These designs will best retain the type and frequency of aquatic habitats that currently exist in the streams, and will provide similar stability and energy. The replacement design for existing natural design channels employs width to depth ratios, entrenchment ratios, and sinuosity ratios similar to, or better than, the current conditions. Replacement of trees, cultivation of diverse vegetation, and other enhancements that control erosion and runoff will enhance the quality of the existing stream and riparian habitats. Migration of aquatic species will come from upstream or downstream locations to ensure no loss in the gene pool of native species.

The proposed mitigation will consist of stream creation with enhancements which will include: the creation of floodplains as land-use and topography allow; constructing appropriately designed channels; installation of in-stream structures that will allow for aquatic habitat, as well as provide erosion and grade control; and planting riparian vegetation to provide stability along the banks. Such improvements are intended to promote a positive biological response within the stream's aquatic communities. All of the final mitigated streams will be designed to handle their respective drainage areas and will be measured for success by incorporating the principles for a stable stream channel as developed by Dave Rosgen. Added benefit will come with the selective planting of predominately hard-mast producing tree species, added structure to the streams, and floodplain creation as land use allows.

#### Open Water

The amount of post-mining open water will be at least 20.0 acres. The small open waters found in the permit may be replaced as contours allow, or incorporated into the final cut lakes. This increase in open water is beneficial to many terrestrial and aquatic communities. The stream mitigation will not be allowed to intersect open waters but side streams may be constructed at an elevation above the bankfull depth of the mitigated streams which will allow recharge of the open waters during substantial rainfall events by allowing greater than bankfull depths to flow into the open water body as depicted on Map D8 in Appendix A. The addition of open water will foster an increase in aquatic, terrestrial, and avian biological diversity. The open water will provide a refuge for aquatic biota during low and no-flow periods that may otherwise be detrimental to reproduction and migration. Open water bodies may also extend the annual base flow period and benefit migration and reproductive efforts of existing biota. Some permanent open waters will eventually develop into wetlands on a timetable that is dependent on the amount of siltation and the volume of the water body. These wetlands will further enhance and expand the existing aquatic and terrestrial habitat.

#### C. Functional Replacement

1. In-Kind versus Out-of-Kind
2. Holistic Aquatic Ecosystem Context (i.e. stream and wetland interactions)
3. Watershed/Landscape Context

All mitigation will be in-kind and on-site except for the supplemental off-site Buttermilk Creek mitigation plan to compensate for temporal losses.

#### Wetlands

The wetland mitigation locations are shown on Map C in Appendix A. The mitigation locations will be in the flood plains of the stream mitigation which will ensure that wetland hydrology will be established. Any mitigated streams in the wetland areas will be constructed so the bankfull depth elevation is extended away from the channel towards the wetland forming a terrace which transitions into the wetland at a lower elevation. This will ensure adequate overbank flooding and provide the conditions for hydric soils to develop. The remaining criteria to be met will be the introduction of hydrophytic vegetation. See Map D6 in Appendix A for a typical plan and profile view of the wetland mitigation. The hydrophytic vegetation will consist of those species listed in the Wetland Seeding and Planting Stock Summary table in Section 3.

#### Streams

The stream mitigation locations are shown on Map C in Appendix A. The general topography and geomorphology will be similar to the pre-mining conditions, and replaced streams will be designed and constructed so that pre-mining connectivity is maintained. This design will best facilitate effective sinuosity and stream slope, and confine the streams to the center of the post-mine valley configurations, allowing for a plentiful belt width and providing adequate room for meanders and a wider flood plain. Channels will be vegetated with the herbaceous species listed in the Forest/Wildlife Habitat for Stream Buffer Planting Stock Summary table in Section 3.

The mitigation plan proposes to reconstruct and enhance a total of 85,024 linear feet of streams implementing natural design. Typical stream sections are located on Maps D1 through D5 in Appendix A. The bottom stream width is dependent on the reclaimed slope, watershed areas, the target bankfull discharge and preferred depth of flow. The wider bottom configuration will slow the water velocity and control down cutting. On some of the lesser sloped areas, the belt width of the stream will be as low in elevation as the bankfull depth, which will allow for more out of channel flows; aiding in energy dissipation, erosion control, and growth of the riparian buffer. Under certain conditions this design could lead to wetland development. The combination of a wider bottom, use of shallow to deep pools, planting riparian buffers on each side of the streams with hard-mast producing species, and construction of a wider floodplain in some areas will result in an enormous enhancement from this project. Various in-stream structures may be employed to further enhance the streams as shown in Appendix E. This mitigation will produce approximately 21.9 acres of jurisdictional waters and 294.7 acres of riparian habitat and replace all streams that are proposed to be impacted by the mining operation.

The incorporation of a riparian buffer along all the streams provides additional benefit. These buffers offer feeding, reproduction, and refuge habitat for invertebrates, fish, waterfowl, amphibians, birds, and mammals. Riparian buffers also provide the following functions to streams: 1) controls temperature which influences the content of dissolved oxygen of the water; 2) improves water quality: the vegetation retains sediment and pollutants from overland flow and during flood events and increases uptake, storage, and release of nutrients into and out of the aquatic environment; 3) retains waters during storm events and releases it slowly over time contributing to a longer base flow; 4) stabilizes stream banks and controls erosion and sedimentation; 5) furnishes a source of wood to the stream for cover and refuge habitat for fish and sediment storage areas; 6) provides near-bank cover; 7) provides a source of roughness to the stream; and 8) produces leaves, twigs, and insects to the stream, which is important as a food and nutrient source for fish and other aquatic animals. Riparian buffers that are located within a floodplain have additional benefits by reducing the depth of instream flow during flood events which lowers the sediment carry capacity of the stream. The flood velocities are also reduced which limits scour in the channel and promotes sediment deposition on the floodplain.

The following is a comparison of the existing floodplain to the estimated post construction floodplain. The two most critical elements for a successful stream are access to its floodplain and adequate floodplain storage. Floodplains function to convey floodwaters and provide storage. Reduction of flood velocities and normalizing of flood peaks aid in decreasing flood damage and soil erosion. Sedimentation is reduced by allowing suspended particles to be transported out of the channel banks and be deposited across the landscape. This "overflow" filters nutrients and impurities, facilitates infiltration and groundwater recharge, and reduces low surface flows. The following table provides a comparison of the existing floodplain for the streams in the permit to the proposed mitigated floodplain.

Floodplain Width Analysis						
Pre-Mine Floodplain Width with Post-Mine Floodplain Width	Area 1	Area 2	Area 3	Area 4	Area 5	Entire Area
<b>Intermittent Streams</b>						
Average Stream Pre-Mine Floodplain Width	5.3	13.4	13.3	0	0	12.8
Average Stream Post-Mine Floodplain Width	20.9	52.8	38.3	0	0	37.9
Ratio Increase	3.9:1	3.9:1	2.9:1	0	0	3.0:1
Post-Mine Estimated % Increase in Floodplain Width	291.0%	294.0%	186.9%	0	0	196.8%
<b>Ephemeral Streams</b>						
Average Stream Pre-Mine Floodplain Width	3.7	7.3	4.9	0	0	4.8
Average Stream Post-Mine Floodplain Width	16.3	31.8	17.1	0	0	17.1
Ratio Increase	4.4:1	4.4:1	3.5:1	0	0	3.6:1
Post-Mine Estimated % Increase in Floodplain Width	337.9%	338.6%	250.1%	0	0	255.1%
<b>All Streams</b>						

Average Stream Pre-Mine Floodplain Width	4.13	9.30	6.58	0	0	6.48
Average Stream Post-Mine Floodplain Width	17.46	38.80	21.37	0	0	21.45
Ratio Increase	4.23:1	4.17:1	3.24:1	0	0	3.31:1
Post-Mine Estimated % Increase in Floodplain Width	322.8%	317.2%	224.5%	0	0	231.1%

Floodplain Acreage Analysis						
Pre-Mine Floodplain Acres with Post-Mine Floodplain Acres	Area 1	Area 2	Area 3	Area 4	Area 5	Entire Area
<b>Intermittent Streams</b>						
Existing Acres of Floodplain	0.3	0.8	14.5	0	0	15.8
Post-Mine Estimated Acres of Floodplain	1.3	3.5	39.0	0	0	44.2
Ratio Increase	3.98:1	4.2:1	2.69:1	0	0	2.81:1
Post-Mine Estimated % Increase in Acres in Floodplain	297.5%	319.8%	169.2%	0	0	180.9%
<b>Ephemeral Streams</b>						
Existing Acres of Floodplain	0.4	0.2	8.7	0	0	9.2
Post-Mine Estimated Acres of Floodplain	1.6	1.1	32.0	0	0	34.1
Ratio Increase	4.4:1	4.4:1	3.7:1	0	0	3.7:1
Post-Mine Estimated % Increase in Acres in Floodplain	336.5%	338.2%	268.5%	0	0	272.1%
<b>All Streams</b>						
Existing Acres of Floodplain	0.7	1.1	23.2	0	0	24.9
Post-Mine Estimated Acres of Floodplain	2.8	4.5	71.0	0	0	78.3
Ratio Increase	4.18:1	4.24:1	3.06:1	0	0	3.14:1
Post-Mine Estimated % Increase in Acres in Floodplain	318.4%	323.9%	206.3%	0	0	214.4%

#### D. Identification of Potential Challenges

1. Identify the potential challenges to the mitigation plan such as flooding, drought, invasive species, seriously degraded conditions, adjacent property problems, animal/waterfowl degradation of planted species, etc., that could pose a risk to the proposed mitigation.

There will always be challenges to the proposed mitigation and corrective actions will be actively implemented should adverse situations occur. This will ensure that the success of the mitigation is achieved. Physical challenges such as seriously degraded land conditions contributing to bank instability resulting in erosion may occur, an example being that stream banks may become unstable due to the sparse vegetation during early stages of reclamation. This erosion causes an increase of sediment into the streams. Headcuts may also start at a nick point where the stream tries to adjust its energy gradient. This may lead to incision down to the spoil. There is potential for portions of the mitigated streams becoming non-jurisdictional which is largely a result of insufficient drainage areas to the headwater streams. Potential challenges for the wetland mitigation include the weather (either too much or too little precipitation), wildlife foraging on the newly planted woody species, and vigorous invasive species.

Under SMCRA regulations, coal companies are required to return the land to a productive state. Peabody Midwest Mining, LLC has received numerous awards for reclamation and has successfully minimized adverse impacts by using methods such as placing thick lifts of soil over the spoil, properly handling any acidic overburden, ripping the soil to minimize compaction, and revegetating shortly after regrading. Peabody Midwest Mining, LLC uses individuals who are skilled at planting and maintaining trees as well as constructing streams to ensure success of the mitigation.

**A performance period up to 10 years will provide enough time to ensure the success of the mitigation areas.**

2. Discuss how the mitigation plan accommodates these challenges along with potential remedial measures in the event that mitigation does not meet performance standards.

Peabody Midwest Mining, LLC will implement corrective measures as necessary to ensure the success of the mitigation. Corrective actions for the stream mitigation will include using engineered structures that redirect the flow away from the banks reducing erosion until the vegetation becomes firmly established along with replanting or overseeding areas where vegetation seems sparse. To control headcutting, grade control

structures such as cross vanes or constructed riffles will be utilized to prevent migration of the headcut into the spoil. If a stream becomes non-jurisdictional, attempts will be made to direct additional runoff to the stream. Corrective actions for wetland challenges will include replanting vegetation, eradicating invasive species, and performing minor earthwork to maintain the appropriate hydrologic balance.

- II. Provide a written narrative of environmental goals and objectives. These goals and objectives should be directly produced from the information gathered under Section 1: Baseline Information for the proposed impact site. Explain the theory/rationale behind selection of different components of the mitigation site and how those components compensate for the proposed impacts. Include a statement concerning the viability of the mitigation at the proposed location.

Wherever possible, disturbance of jurisdictional wetlands and streams should be avoided. When disturbance is unavoidable, the disturbances should be minimized.

### Goals

The goal of the mitigation is to provide a no net loss of wetland area while improving hydrologic and habitat functions and to replace stream and riparian buffer functions temporarily lost by the proposed project.

### Objectives

1. Reconstruct a total of 85,024 linear feet of a naturally designed channel at the mine site for the 126,686 linear feet of ephemeral and intermittent streams that will be impacted by the surface mining of the bituminous coal reserve at the Bear Run (Amendment 4) site.
2. Increase wetland area at the mine site by creating a total of 56.0 acres of palustrine forested wetlands for the 10.42 acres of PFO, 0.80 acre of PSS, 10.85 acres of PEM, and 5.39 acres of PUB wetland types that will be impacted by the surface mining of the bituminous coal reserve at the Bear Run (Amendment 4) site.
3. Objectives for the natural design stream mitigation include enhancements in stream stability and function over the existing streams at the Amendment 4 area by improving fish habitat and diversity, stabilizing bed and banks by using natural methods rather than armoring, adding riparian habitat, reducing flood levels by allowing access to a floodplain, developing riffle, run, and pool complexes, routing sediment, conveying surface water, and creating a natural look.
4. Improved wetland functions will include increasing wetland area and flood storage capacity, increasing vegetation cover, and promote hard-mast producing species.

### Section 3: Mitigation Work/Implementation Plan

#### I. Site Preparation:

##### A. Plans – Describe plans for the following criteria:

1. Grading
2. Hydrological changes
3. Water control structures, if any
4. Exotic vegetation control
5. Erosion control
6. Bank stabilization, if applicable
7. Equipment and procedures to be used
8. Site access control
9. Strategy for minimizing soil compaction
10. Stream Pattern, Profile, and Dimension
11. Other

As-built plans will be submitted with the annual monitoring report for any streams that were completed in the previous year. The following is general information that will be used, but any specific dimensions or distances will be developed for the site specific stream based on the reclaimed slope and watershed areas. The proposed natural design mitigated channels will achieve a natural dynamic equilibrium. This will ensure to the greatest degree possible, a stable mitigation effort. Designing mitigation to randomly traverse the landscape only invites the opportunity for failure from uncontrollable erosion.

The stream mitigation design will be dependent primarily on reclaimed slope criteria as well as watershed size and will be assessed utilizing the drainage types listed in the Rosgen Channel Morphology Matrix table found earlier in this permit application narrative. In areas of steeper slopes (4-10 percent), an "A" type channel will typically be utilized. In areas of moderate to flatter slopes (2-3.9 percent), a "B" type channel will typically be utilized. In areas of flatter slopes (<2 percent), a "C" type channel will typically be utilized in combination with a "B" type channel in areas that will not incorporate an enhanced floodplain. Also in areas of flatter slopes (<2 percent), an "E" type channel maybe utilized in areas that incorporate an enhanced floodplain. Typical post-mining profiles and typical cross-sections for the mitigated streams are provided in Map D1 in Appendix A. Sinuosity, meander lengths, and amplitudes, etc. are necessary components to successful construction of the proposed mitigation.

A combination of tools will be utilized for development of the natural design stream mitigation. Information is gathered from the reclaimed watershed which includes the drainage area, topography of the drainage area, valley slope, valley width, and valley length. The overall valley slope is used to determine the type of stream that will be reconstructed. A slope greater than 4% will typically utilize "A" type stream parameters, a slope that ranges from 2 to 4 percent will typically utilize "B" type stream parameters, and slopes less than 2 percent will typically utilize "C" or "E" type stream parameters. The parameters that will be used in the design include sinuosity, width/depth ratios, and entrenchment ratios. *Natural Regrade*<sup>10</sup>, of the Carlson Survcadd product line, will be used to develop the plan form of the stream mitigation utilizing the appropriate sinuosity consistent with the Rosgen channel type being designed. The profile of the stream is adjusted within the limits of the Rosgen ranges to balance the cut/fill. *Natural Regrade* helps in landscape design to mimic the functions of a natural landscape. These evolve over time due to the physical and climatic conditions present at the site to establish water and sediment transport in a stable hydrologic equilibrium.

Once *Natural Regrade* has been used, the slope and length of the stream mitigation is used in *Sedcad*<sup>11</sup> or the drainage area is used in the mini-regional curves to design the bankfull cross-section.

*Sedcad*<sup>11</sup> is a hydrology and sedimentology program that is primarily used in the mining industry to design and evaluate surface water, erosion, and sediment control systems using established methodologies for hydrologic and hydraulic analysis. Drainage networks can be created to model how ditches, culverts, and sediment basins respond to various storm events. To determine the bankfull cross-section for the stream mitigation using *Sedcad*, the following steps are performed: 1) design storm is entered, 2) network is entered, 3) watershed information is inputted for hydrograph and sedimentgraph modeling, and 4) control structure is entered (i.e. channel cross-section, pond, etc.). The output shows how the design storm discharge flowing through the network reacts in the control structure (i.e. cross-section) by providing the depth of flow, top width, velocity, cross-sectional area, and hydraulic radius. The bankfull cross-section is sized to accommodate the 2-year 1-hour precipitation event with the proper width-to-depth ratio for the designed stream type.

Another tool to be used to aid in natural design stream mitigation will be the mini-regional curves that were developed in conjunction with Stantec Consulting Services Inc. from Jeffersonville, Indiana for southwestern Indiana and submitted in a report entitled, *Mini-Regional Curve Development Southern Indiana*<sup>30</sup>, which can be found in Appendix M of this permit. Information collected throughout the region at reference streams in both mined and non-mined sites were used to develop regional curve relationships to primarily evaluate cross-sectional area (both bankfull area and inner berm area) versus drainage area. The resulting regional curve for bankfull cross-sectional area closely resembles the USGS curve produced for Ohio's Region A. Additional curves for bankfull width and mean depth were also produced. A regional curve for discharge was also developed although there would not be sufficient data to draw defensible conclusions regarding discharge due to the lack of suitable USGS gage sites within the study area. To determine the bankfull cross-section for the stream mitigation using mini-regional curves, the drainage area for the stream mitigation is used to estimate the cross-sectional area of both bankfull and the inner berm. The areas are engineered to have the proper width-to-depth ratio for the designed stream type. A properly designed and constructed inner berm feature will allow for channel adjustments (e.g. minor aggradation/degradation) without threatening the integrity of the project and will enhance low flow ecology.

Engineered structures will be added to the mitigated stream to maintain stability. See Appendix E for details of structure installation. These structures could consist of, but not be limited to, rock or wood riffles, rock or wood j-hook vanes, rock or wood cross vanes, shallow to deep pools, root wad revetments, and large boulders. Structures that are typically utilized in stream mitigation are log vanes, root wads, and down-cut protection structures (cross-vanes). The down-cut protection structures provide protection from head-cutting until the immediate stream watershed is fully vegetated. Root wads are placed in the outer banks of the stream in the curves to protect it from erosion as well as helping in pool development. The pools develop adjacent as well as underneath these structures. The log vanes decrease the near bank stress by deflecting the stream flow energy back towards the center of the stream particularly in the curve and deflection areas. The engineered root wad revetments, log vanes, or strategically placed rocks located on the outer bank areas of the curves will be placed in the edge of the engineered pools to provide bank stabilization and shading of some of the pool area to provide water temperature control, as well as a safe haven for biological life. Geotextile fabric is keyed in with each stream structure to hinder erosion around and under a structure. The fabric prevents water and stream substrate from washing away causing the structure to fail. Correct geotextile fabric placement is essential to in-stream structure success. Willow cuttings or erosion control nets will also be utilized early in stream construction to protect the banks from erosion particularly in the curves as needed. It has been observed that willows, which are not on the approved riparian planting list, form dense stands at the stream water and bank interface. The willows migrate along the water's edge providing natural bank stability, shading of the stream, and biological habitat.

Riffle and pool complexes will be installed using nontoxic/nonacid forming mine rock of various sizes, commercial grade riprap and/or woody materials from previously downed trees and will be modified as necessary to achieve successful mitigation. As illustrated on Maps D2 to D5 in Appendix A and Appendix E, engineered riffle material will be embedded in the substrate and will provide energy dissipation and protection from down cutting. The pools will be constructed with shallow to deep areas primarily in the curve areas and secondarily in the straight stretches to provide energy dissipation and provide a suitable biological habitat area. The structures may need to be modified somewhat as the stream is constructed from the typical plans shown on Maps D2 to D5 in Appendix A.

Adjustments to the mitigated stream features (i.e. additional riffle structure, channel blockage, bank stability) will be implemented as needed for continued success. Additional riffles and pools will form naturally in response to channel hydraulics, storm events, and sediment bedload as the stream matures. The engineered structures and natural structures will provide stream stabilization, aquatic function, and help ensure the success of the mitigation.

Standing dead timber or other raptor perches will be placed along the edges of the riparian buffers. By providing perches, the rodent population within the riparian buffers can be moderated. Moles, field mice, and particularly, voles love to eat succulent root systems and will burrow under the bare root seedling and container trees and eat away until the plant is dead or crippled. If the stream mitigation abuts a forested area, the use of perches may not be necessary. The perches may be nothing more than resting a tree obtained during the initial land clearing with the root ball in the ground with the tree branches up.

Additional aquatic and riparian habitat enhancement measures specified within the permit include:

- placing a 50-foot riparian buffer on each side of the natural design ephemeral stream mitigation and a 100-foot riparian buffer on each side of the natural design intermittent stream mitigation to provide woody debris for habitat and allochthonous material downstream,
- replacement of brush, shrubs, and trees for stream cover and temperature control, vanes and similar structure to re-direct flow energy and provide macro-invertebrate habitat,
- riffles and similar structure to increase aeration,
- shallow and deep water areas to increase habitat diversity,
- the spatial placement of large woody debris or rock piles adjacent or abutting the channel to provide important habitat structure during the riparian buffer maturation period, and
- meanders in the stream to add fluid geomorphology

Reconstructed streams will not be routed through impoundments after SMCRA final reclamation bond has been released, unless the streams previously flowed through impoundments. However, permanent or temporary impoundments may intersect the replaced stream channels prior to then. These impoundments will initially serve as a sediment control measure that will subsequently provide water storage, flood mitigation, and additional habitat diversity for breeding and shelter of aquatic life. The permanent structures may partially develop into wetlands that will further enhance and expand the existing aquatic and terrestrial habitat diversity. The addition of open water and expanded wetland features to the stream will likely foster an increase in aquatic, terrestrial, and avian biological diversity. The open water will provide a refuge for aquatic biota during low flow and no-flow periods that may otherwise be detrimental to reproduction and migration.

Prior to SMCRA final bond release, the temporary basins will be backfilled and the permanent basin drainages will be partially removed and rerouted around the open water. Streams may be connected to open waters at an elevation above the bankfull depth. This will allow the recharge of the permanent basin during substantial rainfall events by allowing greater than bankfull depths to flow into the water body, while maintaining the connectivity of jurisdictional waters. The proposed location of the mitigation for the streams, wetlands, and open waters is found on Map C in Appendix A. The locations of the mitigated waters and wetlands are subject to change, but the general language of this permit application will be followed. Any modifications to the proposed mitigation language will be submitted to the Newburgh ACOE field office for prior review and approval.

B. Soils/Substrate

1. Wetlands:

- a. Indicate whether or not the site has been scraped, filled previously, tiled, plowed, etc.

Mitigated wetlands will be constructed in reclaimed areas once mining has been completed. Topsoil from any wetland over one (1.0) acre in size will be saved separately, stockpiled, and placed on any of the wetland mitigation areas. Any wetland soils that contain *Phragmites* or other invasive species will not be segregated for use on wetland mitigation areas. Soil replacement operations will be conducted to minimize compaction of the reclaimed soils.

- b. Identify the original source of any soil transported to the mitigation site. Soil origin is important if the applicant is proposing to use the seed bank from an impacted wetland.

All soil that will be replaced in the permit area will be obtained from the area. No additional material will be transported to the mitigation site. **Standard soil testing and analysis will be performed every 2 years at a minimum spacing of one sample per 3 acres in areas of wetland mitigation. The results will be provided with the annual monitoring report.**

2. Streams:

- a. Identify type of substrate present (e.g., boulders, cobble, pebbles, etc.) and the particle size distribution (e.g., pebble counts); channel habitat types (pools, riffles, runs, etc.)

Mitigated streams will be constructed in reclaimed areas once mining has been completed, and the area has been resoiled. These soils have naturally occurring gravels mixed in them and will be used in conjunction with non-acidic/non-toxic mine-run rock to form the substrates. Riffle structures constructed of rock materials will be utilized to increase aeration, stabilize the substrates to prevent down-cutting, and help in the development of pool complexes. Pre-mine soils are mixed by heavy equipment during removal and replacement operations. Soil replacement operations will be conducted to minimize compaction of the reclaimed soils.

- b. Identify the type(s) and original source of any substrate transported to the mitigation site.

All soil that will be replaced in the permit area will be obtained from the area. Material for j-hooks, riffles, etc. will be transported from rock quarries, etc. or will utilize non-acidic/non-toxic mine run rock. [Standard soil testing and analysis will be performed every 2 years at a minimum spacing of one sample per 3 acres in areas of riparian mitigation. The results will be provided with the annual monitoring report.](#)

C. Hydrology

1. Identify the source of hydrology/water supply, estimated size of the watershed and connections to existing waters and proximity to uplands. In some areas, a water budget may also be necessary. Designs that manipulate wetland and stream processes with engineered structures and features, which require maintenance intensive plans, should be avoided.
2. Provide general information on the average frequency, depth and duration of water available to the site under normal conditions.
3. Install ground water monitors/piezometers to help evaluate groundwater elevations and/or flow (\*this will be determined on a case by case basis by the Louisville District).

All mitigated streams and wetlands will be located in valley areas with sufficient upstream drainage to provide surface runoff to maintain the wetland areas with hydric conditions and to maintain the streams appropriate pattern and profile. Reclamation that occurs in surface coal mining operations allows the land to be graded for suitable wetland and stream development.

Permanent post-mine impoundments (open water bodies) will help to provide some flood storage for surface runoff. Flood storage will reduce peak stream discharge and help maintain a longer base flow in streams and to wetland areas. Water in the permanent impoundments also recharges the groundwater table in the spoil. The addition of open water impoundments is an important aquatic habitat resource for the permit area.

Primary roadways will be reconstructed after mining per agreements with the Sullivan County commissioners. Each primary roadway will be designed in compliance with the following design standards. the embankment foundation shall be clear of all organic materials and shall be scarified, fill material shall be free of sod, large roots, and other vegetative matter and benched in if cross-section is steeper than 8:1, the fill shall be brought up in horizontal layers of such thickness as required to facilitate adequate compaction, side slopes shall be no steeper than 2:1, and embankments shall have a minimum top width of  $(h+35)/5$ , where "h" is the embankment height as measured from the natural ground at the downstream toe to the top of the embankment. Each primary roadway will be reconstructed to have adequate drainage control, using structures such as, but not limited to, the following: bridges, culverts, box culverts, and spans. The drainage control system will be designed to safely pass the peak run-off from a ten (10) year, six (6) hour precipitation event or greater event as specified by Sullivan County surveyor for county road crossings.

Typically, the same type of structure (bridge for a bridge, culvert for culvert) will be installed during reclamation. Safe and stable stream crossings that can accommodate wildlife and protect stream health will be evaluated for use when natural design stream mitigation is proposed on either side of a primary roadway. Effective crossings could include bridges, open bottom arches, and culverts that span, and are sunk into, the stream bottom. Culverts would be embedded at least one foot for box culverts and pipe arches, or at least 25% of the pipe diameter for pipe culverts. The primary road sections that are proposed to be affected by mining are segments of County Road (C.R.) 500 South, C.R. 750 South, C.R. 850 South, C.R., 900 South, C.R. 975 South, C.R. 700 East, and C.R. 600 East. Agreements will be negotiated with the county before the primary roads can be closed and mined through. Roadways will be reconstructed in the reclaimed spoil and specific plans have not been designed or approved. Approvals will be obtained incrementally.

- D. Planting Plan – The planting plan and methods must be described in the proposed mitigation plan. The following information must be incorporated into the planting plan:
1. Provide a table of species to be planted, including numbers, spacing, types of propagules, pots sizes, etc. Scientific and common names must be used, as well as the appropriate indicator status for each species. Use the current regional U.S. Fish and Wildlife Service *National List of Plant Species that Occur in Wetlands*.
  2. Indicate source-locale of seeds, plant plugs, cuttings, etc. Only native plant species may be used for the mitigation site. Hydrophytic vegetation may not consist of exotic or hybrid nursery species. Grass seed mix is commonly used to cover mitigation sites under construction. The use of **annual** non-native species will be considered. The species composition of the mix should be clearly documented, as well as any methods for eventually removing the temporary ground cover, if required (e.g. native, perennial greases).

3. Show planting locations on a base topographic map according to species. The map must include elevations and proposed water levels. Demonstrate, in an attached narrative, that the appropriate plant species are being planted in suitable areas (i.e. elevation, water depth, and soil type) and that the timing of planting will foster successful growth.
4. If transplanting is proposed, consider storage method and duration.
5. Describe any expected volunteer native vegetation that is included in mitigation planning.

The following table contains the plantings to be used for the riparian buffers along the streams. See Map C in Appendix A for the proposed stream and riparian buffer locations.

Forest/Wildlife Habitat for Stream Buffer Planting Stock Summary			
Scientific Name	Common Name	Seeding or Planting Rate	Method of Application
<i>Dactylis glomerata</i>	Orchard Grass	10 lb/ac	Broadcast
<i>Trifolium pratense</i>	Red Clover	4 lb/ac	Broadcast
<i>Bromus</i> spp.	Brome Grass	10 lb/ac	Broadcast
<i>Agrostis alba</i>	Red Top	2 lb/ac	Broadcast
<i>Trifolium hybridum</i>	Alsike Clover	3 lb/ac	Broadcast
<i>Trifolium</i> spp.	Ladino Clover	3 lb/ac	Broadcast
<i>Lolium perenne</i>	Perennial Rye Grass	10 lb/ac	Broadcast
<i>Liriodendron tulipifera</i>	Yellow Poplar	60 container trees or 600 seedlings/ac	Mechanical or Hand
<i>Diospyros virginiana</i>	Persimmon	60 container trees or 600 seedlings/ac	Mechanical or Hand
<i>Quercus</i> spp.	Red Oak species	60 container trees or 600 seedlings/ac	Mechanical or Hand
<i>Quercus</i> spp.	White Oak species	60 container trees or 600 seedlings/ac	Mechanical or Hand
<i>Carya</i> spp.	Hickory	60 container trees or 600 seedlings/ac	Mechanical or Hand
<i>Juglans nigra</i>	Black Walnut	60 container trees or 600 seedlings/ac	Mechanical or Hand

**Note:**

1. For herbaceous plantings, a minimum of 5 species shall be selected for initial planting to ensure diversity. At the end of monitoring, 70% of ground cover will be the planted species and of that no one species will comprise more than 40% of that final cover.
2. For woody plantings, no one species will make up more than 20% of the initial planting. The woody species will be planted on a per acre basis to the total planting rates listed with no one planted species making up more than 25% of the surviving planted stock.
3. **Monitoring will not begin until the trees are a minimum of 30" tall.**
4. The herbaceous plantings will provide adequate ground cover to help protect from erosion and will be monitored and maintained on an as-needed basis.
5. Planting of the herbaceous vegetation will occur in the fall with the woody species being planted during the spring. These seasons are estimates and may be changed due to precipitation/flooding and/or mining plans.
6. Spacing of trees and shrubs will be ~8'x9' for seedlings and ~27'x27' for root production type container trees.
7. Alternate site appropriate species may be substituted dependent on nursery availability and the ACOE approval.
8. Prior to planting the woody species, a final species list will be submitted to the ACOE for prior review and approval.
9. The success standard for bare root seedlings will be 80% survivability of the initial planting list and rates, while the success standard for root production type container trees will be 90% survivability of the initial planting lists and rates.

The following table is the plantings to be used in the wetland mitigation areas. See Map C in Appendix A for the proposed locations.

Wetland Seeding and Planting Stock Summary <sup>6</sup>			
Scientific Name	Common Name	Seeding or Planting Rate	Method of Application
<i>Agrostis alba</i>	Red Top	2 lb/ac	Drilled or Broadcast
<i>Lolium perenne</i>	Perennial Rye	5 lb/ac	Drilled or Broadcast
<i>Echinochloa</i> spp.	Barnyard Grass	5 lb/ac	Drilled or Broadcast
<i>Carex</i> spp.	Sedges [various]	Label Rate	Drilled or Broadcast
<i>Trifolium hybridum</i>	Alsike Clover	3 lb/ac	Drilled or Broadcast
<i>Echinochloa</i> spp.	Japanese Millet	5 lb/ac	Drilled or Broadcast
<i>Astragalus cicer</i>	Cicer Milk Vetch	3 lb/ac	Drilled or Broadcast
<i>Lolium multiflorum</i>	Annual Rye	4 lb/ac	Drilled or Broadcast
<i>Quercus</i> spp.	Red Oak [Obl, FacW or Fac species]	60 container trees or 600 seedlings/ac	Mechanical or Hand

Quercus spp.	White Oak [Obl, FacW or Fac species]	60 container trees or 600 seedlings/ac	Mechanical or Hand
Carya spp.	Hickory [Obl, FacW or Fac species]	60 container trees or 600 seedlings/ac	Mechanical or Hand
Carya illinoensis	Pecan [FacW]	60 container trees or 600 seedlings/ac	Mechanical or Hand

**Note:**

1. For herbaceous plantings, a minimum of 5 species shall be selected for initial planting to ensure diversity. At the end of monitoring, 70% of ground cover will be the planted species of that no one species will comprise more than 40% of that final cover.
2. For woody plantings, a minimum of 5 species shall be selected with no one species will make up more than 20% of the initial planting to assure diversity. The woody species will be planted on a per acre basis to the total planting rates listed with no one planted species making up more than 25% of the surviving planted stock.
3. **Monitoring will not begin until the trees are a minimum of 30" tall.**
4. Planting stock for woody plant species will be native species known to occur in southwest Indiana.
5. The herbaceous plantings will provide adequate ground cover to help protect from erosion and will be monitored and maintained on an as-needed basis.
6. Alternate site appropriate species may be substituted dependent on nursery availability and prior ACOE approval.
7. The success standard for bare root seedlings will be at least 50% survivability of the initial planting list and rates. The success standard for root production type container trees will be at least 90% survivability of the initial planting list and rates.

- E. Exotic and Undesirable Species Control – The plan must outline the methods proposed to prevent the introduction and/or establishment of invasive species such as Reed Canary Grass (*Phalaris arundinacea*), Cattails (*Typha sp.*), and Purple Loosestrife (*Lythrum salicaria*). The plan must also outline a management plan if any of these species are found.

Volunteer invasive, undesirable, and exotic species will be eradicated by several means during the monitoring period. Mowing or tilling can be employed to discourage and eradicate undesirable volunteer tree species. Herbicide treatment could be implemented following the manufacturers' instructions. The specific eradication measures will be determined by the specific site conditions. If the some volunteer species provide beneficial support that warrants them to remain in the mitigation site, a request to not remove those species will be submitted to the ACOE for approval.

- F. Schedule – Time frames for construction of the mitigation site should be clearly documented within the proposal, as well as tentative monitoring times. The applicant should be aware that the *initial planting does not constitute the first monitoring period*. Monitoring of the site should commence in the first full growing season post initial planting.

### Wetlands

The proposed timetable for construction of **on-site** wetland mitigation is the spring of 2016 with herbaceous plantings. Tree planting will occur the following spring. These timetables are subject to change due to the rate of coal extraction, weather conditions, etc., but the general plan will be followed.

**The timetable for completion of the proposed off-site Buttermilk Creek wetland mitigation is by the end of the 2<sup>nd</sup> growing season following permit issuance. The mitigation at Buttermilk Creek will occur long before the vast majority of impacts occur at the Bear Run (Amendment 4) site.**

### Streams

The proposed timetable for construction of the **on-site** mitigated streams is for completion by the fall of 2018. Streams will be constructed as reclamation allows. This timetable is subject to change due to the rate of coal extraction, weather conditions, etc., but the general plan will be followed.

**The timetable for completion of the proposed off-site Buttermilk Creek stream mitigation including Buttermilk Creek restoration, stream creation, and instream structure enhancement is by the end of the 2<sup>nd</sup> growing season following permit issuance. The mitigation at Buttermilk Creek will occur long before the vast majority of impacts occur at the Bear Run (Amendment 4) site.**

- G. Construction Monitoring – Monitor of the construction activities to ensure all aspects of the approved compensatory mitigation plan are completed without incident. This will normally require on-site management of the construction personnel by one or more of the permittee's representatives, who have complete knowledge of the plan and some understanding of soil science, hydrology, botany or plant ecology. The person(s) who prepared the mitigation plan should conduct the monitoring.

### Wetlands

A performance period up to 10 years will be employed to monitor and evaluate success of the wetland mitigation. Appropriate species will be verified by assessing the ground cover type and quality. Woody species will be planted at a rate of 600 trees per acre for seedlings and 60 trees per acre for root production type container trees as listed in the above table titled Wetland Planting and Seeding Stock Summary. Container trees will be cultivated using root pruning methods and shall be 3 gallons in size. The final success standard for bare root seedlings will be at least 50 percent survivability of the initial planting rate of 600 trees per acre from the approved species list. The final success standard for root production type container trees will be at least 90 percent survivability of the initial planting rate of 60 trees per acre from the approved species list. The success standard and evaluation period coincides with the IDNR standards for a forest land use.

Hydrologic conditions will be assessed based upon overbank flooding and installing and monitoring groundwater table wells to verify saturation or inundation within the upper 12 inches of the soil horizon for 14 consecutive days of the growing season per Technical Standard for Water-Table Monitoring of Potential Wetland Sites<sup>48</sup>. Hydric soil conditions will be evaluated using wetland delineation criteria. The annual monitoring reports will document the status of the vegetation, soils and hydrology utilizing the data forms provided for in the Midwest Regional Supplement<sup>28</sup> and provide information to assess the status of the mitigation project.

### Streams

A performance period up to 10 years will be employed to monitor and evaluate success of the stream mitigation. The geomorphic features of the streams will be assessed for their Rosgen<sup>3</sup> characteristics to determine if the natural design constructed is functioning. The streams will also have their physical habitat quality assessed utilizing the USEPA Rapid Bioassessment Protocols (RBP)<sup>29</sup>. Appropriate species will be verified by assessing the ground cover type and quality. For the natural design mitigation, woody species will be planted at a rate of 600 trees per acre for seedlings and 60 trees per acre for root production type container trees as listed in the above table titled Forest/Wildlife Habitat for Stream Buffer Areas. Container trees will be cultivated using root pruning methods and shall be 3 gallons in size. The final success standard for bare root seedlings will be 80 percent survivability of the initial planting rate of 600 trees per acre from the approved species list, while the final success standard for root production type container trees will be 90 percent survivability of the initial planting rate of 60 trees per acre from the approved species list. This success standard and evaluation period coincides with the IDNR standards for a forest or wildlife habitat land use.

### II. As-Built Conditions:

The plan must specify that the applicant will:

- A. Submit a report, including construction documents, to the Corps within six (6) weeks of completion of site preparation and planting, describing as-built status of the mitigation project. If avoidance of existing wetlands and streams is incorporated into the development project design, then describe the as-built status of the development project. Include any deviations from the original plan in the vicinity of, or that will affect the existing wetlands and streams. Submit separate reports for grading and planting work if not completed within six weeks of each other. *Initial planting reports are required but will not be considered as a monitoring report.*
- B. Provide topographic maps showing as-built contours (for streams this would entail measurements of pattern, profile, and dimension) of the mitigation area. Indicate location of plantings and any other installations or structures. Hydrological tables should also be included illustrating the current and project water levels for the mitigation site.
- C. Submit a plan outlining the short and long term management and maintenance of the mitigation site.
- D. Adequately field mark the approved mitigation site with *permanent* signs identifying the mitigation boundaries.

As-built plans will be submitted with the annual monitoring report for any wetlands or streams that were completed in the previous year.

### III. Financial Assurances:

The permittee or party responsible for accomplishing and maintaining the mitigation project, including contingency funds for adaptive management, is responsible for securing adequate funds to accomplish those responsibilities associated not only with the development and implementation of the project, but also its long-term management and protection.

SMCRA requires mining companies to post bonds sufficient enough to cover the cost of reclamation including backfilling the material, stabilizing, capping, regrading, placing cover soils, revegetation, and maintenance; all of which cover the mitigation proposed in this application. On-site mitigation will be utilized but if deemed

necessary to ensure success, off-site mitigation will be proposed and Peabody Midwest Mining, LLC will work with the ACOE to develop a plan for success.

## Section 4: Success Criteria

### I. Minimum Success Criteria:

#### A. Wetlands

Mitigated forested wetlands will be considered successful if the following conditions are met:

1. [The proposed jurisdictional wetland acreage will be met.](#)
2. The final success standard for bare root seedlings will be at least 50 percent survivability of the initial planting rate of 600 trees per acre from the approved species list. The final success standard for root production type container trees will be at least 90 percent survivability of the initial planting rate of 60 trees per acre from the approved species list. This will consist of a minimum of 5 native species known to occur in southwestern Indiana to assure diversity.
3. No one species will make up more than 25 percent of the surviving plant stock.
4. The vegetation present in these areas meets the current federal delineation manual for hydrophytic vegetation.
5. The soils in the mitigated wetlands areas exhibit hydric conditions that must be sufficient to meet the criteria of wetland determination per the 1987 Corps of Engineers Wetland Delineation Manual<sup>4</sup> and the Midwest Regional Supplement<sup>28</sup>.
6. The mitigated wetlands will have flood storage capacity providing sufficient hydrology so the soils are inundated or saturated for [14 consecutive days](#) of the growing season as determined by the installation of groundwater table monitoring wells [per Technical Standard for Water-Table Monitoring of Potential Wetland Sites](#)<sup>48</sup>.
7. The site is self-sustaining after the establishment of the approved permanent vegetation.
8. The site should meet the proposed plantings for the mitigated type. For forested wetlands, expected tree growth will not advance during the 5-year monitoring period to the point where it will qualify as a PFO1A; however, the trees shall be growing, healthy, and indicative of a future PFO1A wetland.

#### B. Streams

Mitigated streams will be considered successful if the following conditions are met:

1. The minimum riparian buffer widths are established.
2. The final success standard for woody species is 80 percent survivability of the initial planting rate of 600 trees per acre from the approved species list for bare root seedlings and 90 percent survivability of the initial planting rate of 60 trees per acre from the approved species list for root production type container trees of the initial planting lists and rates which will consist of a minimum of 5 native species known to occur in southwestern Indiana to assure diversity.
3. No one species will make up more than 25 percent of the surviving plant stock.
4. Rosgen<sup>3</sup> level II and III characteristics will be measured to ensure the development of stable channels for the appropriate slope and drainage area within the watershed. See the Rosgen Channel Morphology Matrix table in Section 1 for the conditions.
5. The stream is self-sustaining after the establishment of the approved permanent vegetation.
6. The streams are jurisdictional.
7. Utilizing the EPA's Rapid Bioassessment Protocol<sup>29</sup>, specific natural streams as shown on the mitigation map shall meet the following minimum scores for success. The final assessed score shall be equal to or exceed 11 for the metrics of pool variability, channel flow status, and channel sinuosity. A minimum score of 6 for each bank shall be measured for bank stability.

### II. Project Specific Success Criteria for Wetlands and Streams:

Each compensatory mitigation plan shall include project specific success criteria that are:

- A. Based on the targeted functions and values of the compensatory mitigation as compared to those identified from a functional assessment of the aquatic resource impacted at the development site.
- B. Measurable
- C. Achievable, based on the purpose of the compensatory mitigation, design of the site, and functional assessment criteria, by the end of the maintenance and monitoring period.

#### Mitigated Wetlands

The success criteria to track progress of the mitigated wetlands will be based on the 1987 Corps of Engineers Wetland Delineation Manual<sup>4</sup> along with the Midwest Regional Supplement<sup>28</sup> utilizing the Wetland Determination Form. Wetland success is achieved by developing an area that has wetland hydrology, hydric soils, and hydrophytic vegetation. These features are measurable and achievable for this permit area.

#### Mitigated Streams

The measurable performance standards to track progress of the mitigated streams will be based on Rosgen stream assessments as developed by Dave Rosgen. The type of stream will be based on Rosgen<sup>3</sup> stream classifications for the appropriate slope and drainage area for a stream. Enhancements to the streams such as adding sinuosity, decreasing entrenchment of the channel, developing riparian buffers, installing riffle, run, and pool complexes, and adding a floodplain as post-mining land uses allow are all measurable, achievable, and verifiable assessment criteria to obtain success.

III. Include measurable performance standards to track progress toward achieving the success criteria.

#### Mitigated Wetlands

The measurable performance standards to track progress of the mitigated wetlands will be based on the 1987 Corps of Engineers Wetland Delineation Manual<sup>4</sup> along with the Midwest Regional Supplement<sup>28</sup>. Wetland success is achieved by developing an area that has wetland hydrology, hydric soils, and hydrophytic vegetation.

#### Mitigated Streams

The measurable performance standards to track progress of the mitigated streams will be based on Rosgen stream assessments as developed by Dave Rosgen. Stream success is achieved by developing a natural stream channel that has a stable cross-section, stable meander pattern, and a stable profile such that over time, the channel features are maintained and the stream maintains stability. See the Rosgen Channel Morphology Matrix table in Section 1 for the parameters.

All of these performance standards will be addressed in the annual monitoring reports.

## Section 5: Monitoring

### I. Monitoring Reports:

Annual reports should be sufficient unless there are any unforeseen circumstances that might put the potential success of the project into question. In that case, biannual reports may be required. All annual reports will be submitted to the District by January 30th for the previous year.

- A. Timing
- B. On-Site Method
- C. Documentation

Annual monitoring reports for the mitigated wetlands will be provided for each wetland and be based on information obtained at set monitoring points which will be clearly identified in the field. There will be a minimum of one monitoring point for each wetland or for every 3 acres of a larger wetland. Included in the reports will be wetland delineations utilizing the Midwest Regional Supplement<sup>28</sup>, a narrative assessment describing the wetland and vegetation, photographs from each monitoring point, tree counts, groundwater table monitoring reports, soil testing results, water quality sampling data, and results from monitoring certain variables of the ACOE Hydrogeomorphic Method (HGM). As-built plan drawings of the areas constructed or planted will also be provided in the first report. Tree counts will be conducted using techniques appropriate to the site, i.e. one-fifth acre or twenty-foot or fifty-foot radius circular plot.

For each wetland site adjacent to stream mitigation, a row of 3 wells will be installed equidistant from one another between the top of the stream bank and the wetland/upland boundary. Approximate locations are shown on Map G in Appendix A. The water levels will be measured either manually or with automated equipment. At locations subject to flooding, depth of surface water will be noted in the measurements. Water table monitoring reports will chart the depth of saturation during the growing season (approximately March 15 - June 1) for the installed groundwater well. Standard soil testing and analysis will be performed at the monitoring point and submitted every 2 years. Internal stream/wetland water quality monitoring as detailed in the Surface Water Sampling Plan for Streams and Wetlands (Section 1.8) will be included in the annual report for the locations shown on Maps G (pre-mining) and H (post-mining), as applicable.

The variables that will be used to show a functional increase in the wetland mitigation using the ACOE Hydrogeomorphic Method (HGM) shall include amount of organic detritus on the ground, water table depth and steady water changes resulting in no flash events to flush out organic debris. Regional reference standards will be developed from existing wetland mitigation sites on both reclaimed and natural sites. Potential reference sites will be the wetlands at Wildcat Hills Mine - Cottage Grove Pit and Eagle Valley Pit, Jenlin Pit, Farmersburg Mine, and Francisco Mine. Information on the specific reference standards will be submitted as existing data is collected and the standards are set. Project targets will be set for the particular variables which are consistent with the restoration or creation goals, because it has been determined that these particular variables are necessary factors for the hydrologic, biochemical, or habitat functions to occur. Once success and acreage requirements have been achieved, final wetland delineation will be performed with a meets and bounds to determine the final acreage and a request to release the mitigated wetland from further monitoring will be submitted.

Annual monitoring reports for the mitigated streams will be provided for each stream once the majority of the riparian plantings reach a minimum of 30 inches in height. Assessment locations will be set every 1,500 linear feet of stream length and will be clearly identified in the field. Included in the reports will be a completed Rosgen Level II and III modified stream assessment along with the Habitat Assessment Field Data Sheet utilizing the USEPA Rapid Bioassessment Protocols (RBP). In addition to these assessments, the report will include a site map, stream cross-sections, stream profiles, a narrative description noting the total lengths and acreages constructed, any areas of instability along with any structures that have been placed or naturally developed in the channel along, and if the mitigation is meeting the mitigation goals, a description of the adjacent riparian buffer including widths and diversity of species, photographs from each assessment points, tree counts and soil testing results in the riparian buffer, biological sampling, and water quality sampling data. Internal stream/wetland water quality monitoring as detailed in the Surface Water Sampling Plan for Streams and Wetlands (Section 1.8) will be included in the annual report for the locations shown on Maps G (pre-mining) and H (post-mining), as applicable. As-built plans for streams that were constructed the previous year will be submitted. Evaluation of any enhancements will detail the added value over the pre-mining conditions (i.e. stable slopes, widened floodplain to dissipate energy and increase the riparian habitat value, etc.)

The success standard for the woody plantings will be verified by the appropriate tree counting technique, i.e. one-fifth acre or twenty-foot or fifty-foot radius circular plot. Tree counting techniques will be conducted for every 1,000 foot of riparian buffer. Standard soil testing and analysis will be performed at the monitoring point and submitted every 2 years. Biological sampling, at the locations shown on Map G, will be conducted to obtain a macroinvertebrate Index of Biotic Integrity (mIBI) and a fish Index of Biotic Integrity (fIBI). This yearly sampling will be conducted after the riparian buffers are planted and be performed at the locations shown on Map G (pre-mining) and H (post-mining). Once success and linear footage requirements have been achieved, a request to be released from monitoring will be submitted.

Annual monitoring reports will be submitted to the ACOE for a period up to 10 years by January 30th for the previous year and include information collected from biannual monitoring inspections. After the fifth year of annual monitoring, the ACOE will be petitioned for biennial monitoring. Biannual monitoring will consist of at least one complete inspection at each assessment point and at least one visual maintenance inspection for each stream reach or wetland area. Data collected during the complete inspection includes:

Component	Data Collection
<u>Wetland Monitoring</u>	
Cowardin	Midwest Regional Supplement
	Photographs
Hydrology	Groundwater Table Monitoring Wells
Habitat	HGM variables
Vegetation	Tree Counts
	Photographs
	Soil Testing
Chemical	Stream/Wetland Water Quality
<u>Stream Monitoring</u>	
Geomorphology	Rosgen Level II and III Assessment
	Plan and Profile/Cross-Sections
	Photographs
Habitat	RBP
Vegetation	Tree Counts
	Photographs
	Soil Testing
Biological	mIBI
	fIBI
Chemical	Stream/Wetland Water Quality

Note: The above schedule is repeated for monitoring years 6 through 10, unless mitigation is considered successful and monitoring is no longer required.

Data collected during visual maintenance monitoring includes an inspection for any significant changes since the last complete inspection and the need for any repairs that are compromising the mitigation success. Any issues identified by the maintenance monitoring will be documented and corrective measures taken.

D. Responsible Parties

Peabody Midwest Mining, LLC f/k/a Black Beauty Coal Company, LLC  
7100 Eagle Crest Boulevard, Suite 100  
Evansville, Indiana 47715  
Contact: Bryce West  
Phone: 812-434-8500

Several individuals are responsible for the design, construction, revegetation, and monitoring of the mitigation for Peabody Energy, but the primary designers will be Richard Williams and Ann Nelson, PE.

Richard Williams, Permit Specialist, has over 20 years experience in surveying, stream assessing, and wetland delineating. Mr. Williams responsibilities have involved wetland delineation, stream assessments, construction from grade staking to final structure placement. He is also involved in designing the plan and profile for the stream mitigation utilizing spoil grade topography provided by the mines.

Richard Williams  
Education and Training

- A.S. in Surveying, Vincennes University - Vincennes, IN 1990
- Wetland Delineation with Emphasis on Soils and Hydrology, Wetland Training Institute, Inc. - Whitefish, MT 2005
- Stream Geomorphology and Ecology, Ohio State University Technical Seminar - Columbus, OH 2005
- Plant Identification, Wetland Training Institute, Inc.- Indianapolis, IN 2005
- SEDCAD 4 Program Training, Evansville, IN 2007
- Plant Identification, Wetland Training Institute, Inc.- Indianapolis, IN 2007
- Applied Fluvial Geomorphology (Level I), Wildland Hydrology, Inc. - Fayetteville, AR 2007
- River Morphology and Application (Level II), Wildland Hydrology, Inc. - Fayetteville, AR 2007
- River Assessment and Monitoring (Level III), Wildland Hydrology, Inc.- Lubrecht Experimental Forest, MT 2008
- Geomorphic Reclamation and Natural Stream Design at Coal Mine: A Technical Interactive Forum - Bristol, TN 2009
- River Restoration and Natural Channel Design (Level IV), Wildland Hydrology, Inc.- Steamboat Springs, CO 2009
- Regional Supplement Seminar and Field Practicum, Wetland Training Institute, Inc.- Frankfort, KY 2010

Ann Nelson, Environmental Engineer, has 4 years of experience in permitting and design experience and 6 years of additional engineering experience. Ms. Nelson will be the lead in developing the cross-sectional dimension of the stream mitigation

Ann Nelson, PE  
Education and Training

- B.S. in Geological Sciences, Indiana University - Bloomington, IN 1995
- B.S. in Civil Engineering Technology, University of Southern Indiana - Evansville, IN 1999
- SEDCAD 4 Program Training, Evansville, IN 2007
- Applied Fluvial Geomorphology (Level I), Wildland Hydrology, Inc. - Fayetteville, AR 2007
- River Morphology and Application (Level II), Wildland Hydrology, Inc. - Fayetteville, AR 2007
- River Assessment and Monitoring (Level III), Wildland Hydrology, Inc. - Dobson, NC 2008
- Regional Supplement Seminar and Field Practicum, Wetland Training Institute, Inc.- Frankfort, KY 2010
- Indiana Registered Professional Engineer - License No. 10606515
- Illinois Registered Professional Engineer - License No. 062-060721

Dan Williamson, Environmental Specialist, has over 26 years of reclamation experience in wetland restoration, managing forests, and planting trees on surface coal mine sites. Mr. Williamson will manage the planting of riparian buffers and wetlands either by consultants or Peabody Energy employees at the mines.

Dan Williamson  
Education and Training

- B.S. in Forestry, University of Kentucky - Lexington, KY 1977
- A.S. in Reclamation Technology, Madisonville Community College - Madisonville, KY 1981

- District Forester, Kentucky Division of Forestry, 2001-2006
- Plant Identification, Wetland Training Institute, Inc.- Indianapolis, IN 2007
- Applied Fluvial Geomorphology (Level I), Wildland Hydrology, Inc. - Fayetteville, AR 2008
- River Morphology and Application (Level II), Wildland Hydrology, Inc. - Steamboat Springs, CO 2009

Allen Eicher, Environmental Specialist, has over 31 years of reclamation experience. Mr. Eicher has received numerous awards for his reclamation accomplishments. These include the 2007 Indiana Department of Natural Resources Excellence in Mining and Reclamation award, 2008 U.S. Department of the Interior National Award for Excellence in Surface Mining Reclamation, and the 2009 Indiana Society of Mining and Reclamation (Vance "Pat" Wiram Award). Mr. Eicher will help in the oversight of the stream mitigation and along with being involved in making repairs.

Allen Eicher  
Education and Training

- B.S. in Biology, Indiana University - Bloomington, IN 1972
- Applied Fluvial Geomorphology (Level I), Wildland Hydrology, Inc. - Fayetteville, AR 2009

Robert Pendleton, Environmental Specialist, has over 2 years of reclamation experience. Mr. Pendleton will help in the oversight of the stream and wetland mitigation and along with being involved in making repairs.

Robert Pendleton  
Education and Training

- B.A. in Business Administration - Finance, Transylvania University - Lexington, KY 2006
- B.S. in Wildlife Management, Eastern Kentucky University, Richmond, KY 2008
- Applied Fluvial Geomorphology (Level I), Wildland Hydrology, Inc. - Shephardstown, WV 2010
- Regional Supplement Seminar and Field Practicum, Wetland Training Institute, Inc.- Frankfort, KY 2010

In addition, to the staff listed above, many other Peabody professionals in engineering and environmental are available, as needed. Several internal and contractor equipment operators have been trained in recent years in the needed techniques for constructing stream and wetland mitigation. These operators will continue to be utilized and build upon each year's experience.

Wetland Services, Inc. is utilized for stream, wetland and biological assessments, stream design and monitoring. Credentials follow:

Michael Sandefur  
Education and Training

- B.S. in Natural Resources/Environmental Protection, Ball State University - Muncie, IN 1991
- Wetland Delineation Certification Program, Wetland Training Institute - Frankfort, Ky. 2007
- N.C. State Stream Morphology Assessment, River Course 101 - Asheville, NC 2008
- N.C. State Natural Channel Design Principles, River Course 201 - Asheville, NC 2008
- Stream Morphology Engineering, Pilot View, Inc. -Asheville. NC 2008
- OSM, Mid Continent Region Technology Transfer, Acid Mine Drainage Workshop - Evansville, IN 2010
- Cypress Agricultural Services, LLC. Managing Partner, 2002 - present
- Indiana State Legislature, Environmental Service Council, Wetlands Committee - Indianapolis, IN 2002
- American Gas Association, Environmental Committee 2001
- Big Creek Wildlife Foundation, President, 1998-present
- Indiana Electric Association, Environmental Policy Group, Chairman, 1994 &1999
- ORSANCO Power Industry Advisory Committee 1994-1999
- Clean Cities - Evansville, IN 1995-1998
- Evansville Chamber Environmental Committee Co-Chairman, 1995
- 12-yr's professional experience

Tim Sandefur  
Education & Training

- BS Wetland Ecology, University of Kentucky - Lexington, KY 2001
- Wetland Delineation Training, WTI - Jacksonville, FL 1997
- WRP Seminar, NRCS - Oakland City, IN 1998

- Regulatory Wetland Seminar, UKY - Lexington, KY 1999
- SWS Regional Conference - Little Rock, AR 2000
- Watershed Watch Training - Geneva, KY 2002
- National Wetlands Conference - Indianapolis, IN 2002
- Assn. of State Wetland Managers - Evansville, IN 2003
- Private Lands Management, KDFWR - Madisonville, KY 2004
- Mine Reclamation for Wildlife Summit - Louisville, KY 2005
- ACOE Stream Guidance - Newburgh, IN 2005
- Indiana Surface Mine Reclamation Technology Transfer Seminar - Jasper, IN 2006
- ACOE "Rapanos" Guidance - Newburgh, IN 2007
- N.C. State Stream Morphology Assessment, River Course 101 - Asheville, NC 2008
- N.C. State Natural Channel Design Principles, River Course 201 - Asheville, NC 2008
- Geomorphic Reclamation & Natural Stream Design on Coal Mines, Presenter - Bristol, VA 2009
- OSM, Mid Continent Region Technology Transfer, Acid Mine Drainage Workshop - Evansville, IN 2010
- Wetland Services President, Henderson, KY 1997-Present
- Pond Creek Watershed Conservancy District, Henderson, KY 2001-present
- Cypress Agricultural Services, LLC. Managing Partner, 2002 - present
- 13-yrs professional experience

Rick Liggett, DC  
Education & Training

- BS in Human Biology, Logan College - Chesterfield, MO 1999
- Doctorate of Human Biology, Logan College - Chesterfield, MO 2001
- N.C. State Stream Morphology Assessment, River Course 101 - Asheville, NC 2008
- N.C. State Natural Channel Design Principles, River Course 201 - Asheville, NC 2010
- Midwest Interim Regional Supplement for Wetland Delineation - Presented by the Illinois Soil Classifiers Association - Geneva, IL 2009
- OSM, Mid Continent Region Technology Transfer, Acid Mine Drainage Workshop - Evansville, IN 2010
- Indiana Society of Mining and Reclamation Annual Conference - Jasper, IN 2009
- 3-yrs professional experience

Stephen S. Jones  
Education & Training

- B.S. in Wildlife Management with emphasis in Freshwater Ecology, Eastern Kentucky University - Richmond, KY 2000.
- Three years conducting macroinvertebrate surveys, identification and technical reports 2008-2010.
- Two years training in fish surveys under Greg Bright of Commonwealth Bio-monitoring, 2009-2010.
- N.C. State Stream Morphology Assessment, River Course 101 - Asheville, NC 2008
- Bat Conservation & Management Workshop, Bat Conservation International - Barree, PA 2009.
- Indiana Society of Mining and Reclamation Annual Conference - Jasper, IN 2009.
- Myotis Sodalis Foraging Habits - Fort Knox, Shepherdsville, KY 2010.
- OSM, Mid Continent Region Technology Transfer, Acid Mine Drainage Workshop - Evansville, IN 2010
- Member of North American Benthological Society
- 9-yrs professional experience

Cody Thayer  
Education & Training

- B.S. in Biology, University of Southern Indiana - Evansville, IN 2007
- N.C. State Stream Morphology Assessment, River Course 101 - Asheville, NC 2008
- Indiana Society of Mining and Reclamation Annual Conference - Jasper, IN 2009.
- Regional Supplement Seminar and Field Practicum, Wetland Training Institute, Inc. - Frankfort, KY 2010
- 3-yrs professional experience

Kyle Bretl  
Education & Training

- B.S in General Resource Management, University of Wisconsin - Stevens Point 2009
- Minors include Soil Science, Wildlife Ecology, Natural Science
- Basic Wetland Delineation, UW-La Crosse Continuing Ed. & Ext. - Waupaca, WI 2008
- Adv. Wetland Delineation, UW-La Crosse Continuing Ed. & Ext. - La Crosse, WI 2009
- Basic Wetland Plants, UW-La Crosse Continuing Ed. & Ext. - La Crosse - WI 2009
- Regional Supplement Seminar and Field Practicum, Wetland Training Institute, Inc. - Frankfort, KY 2010

- Currently Working towards certification as a Wetland Professional in Training by Society of Wetland Scientists
- 1-yr professional experience

Other noted stream consultants from experienced consulting companies are utilized as needed to review and provide advice on construction and design techniques.

II. Assessment of Function/Value Replacement:

The mitigated wetlands will be enhanced over the existing wetlands by utilizing the ratios as found in Section 2 of this permit data. Enhancements over the existing conditions include consolidation of the small areas into a larger area, planting hard mast desirable species, and maintenance to ensure success and self-sustenance.

The mitigated streams are enhanced over the existing conditions and could contain enhanced features such as increasing sinuosity, decreasing entrenchment, establishing riparian buffers, installing riffle, run, and pool complexes, and adding a floodplain as the post-mining land uses will allow.

III. Release from Monitoring:

Monitoring will be completed for a period up to 10 years or upon success of the mitigation. Once mitigation is deemed successful, Peabody Midwest Mining, LLC will request release from further monitoring. The final report for the mitigated wetlands will include a final wetland delineation of the site to confirm not only that wetlands are present but also that the acreage requirements are present. The final report for the mitigated streams will include confirmation that the linear footage requirements are present and the riparian buffer widths area established.

## Section 6: Contingency Plan

### I. Reporting Protocol:

If the minimum success criteria are not met for all or part of the mitigation in any year, Peabody Midwest Mining, LLC will prepare an analysis listing the potential causes of failure and if determined necessary by the ACOE, propose remedial action for pre-approval.

### II. Response to unsuccessful remediation:

Indicate course of action to be taken in the event that the Corps determines the compensatory mitigation cannot be successfully achieved at the intended site.

An adaptive management plan will be developed, if the mitigation fails to meet the environmental goals and objectives of the mitigation plan. If the stream mitigation and riparian buffers fail to achieve target success criteria in terms of channel stability, riparian buffer vegetation, or biological indicators, reasons for failure will be evaluated and adaptive management actions will be planned, approved, and implemented. Contingency measures may include modification of existing structures, addition of new structures, amending the substrate, supplementing tree plantings, and/or modifying post-reclamation contours. Similarly, if the wetland mitigation fails to meet the goals of hydrological regime or vegetative cover, remedial actions will be considered, such as planting alternative species of trees, introducing additional suitable wetland herbaceous plants, and/or modifying post-reclamation contours. Such measures will be addressed through discussions with the ACOE to provide aquatic functions comparable to those described in the mitigation plan objectives.

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## Section 1: Baseline Information

### I. Proposed Impact Site:

- A. A brief **summary** of the proposed impacts and purpose of the project should be included as part of the mitigation plan. Wetland impacts should be defined in acres and stream channel impacts should be defined in linear feet.

The majority of the permit area for this disturbance is a surface coal mine with issued Indiana Department of Natural Resources (IDNR) permit number S-00256-4 located in Sullivan County, Indiana, approximately 5.0 miles southwest of the town of Dugger. A small portion of the permit area is located in an adjacent approved amendment area with IDNR permit number S-00256-1. This area totals 85.4 acres while the Amendment 4 permit area totals 2,581.1 acres. This permit application, which covers an area of 2,666.5 acres, will be named throughout the narrative and attachments as Bear Run Mine (Amendment 4). The purpose of this disturbance is to produce bituminous coal by surface mining methods to facilitate power production for this nation. See Map A in Appendix A for the general location of the permit areas.

For ease of discussion, this permit is broken into five areas. Area 1, which is located in the approved IDNR S-00256-1 permit, totals 85.4 acres. The majority of this area is situated in the watershed of Buttermilk Creek with a small portion draining to Middle Fork Creek. The remaining areas are located in the issued S-00256-4 permit. Area 2, which is in the watershed of Middle Fork Creek, totals 42.3 acres. Area 3, which drains to Maria Creek, Pollard Ditch, or Brewer Ditch, totals 2,423.3 acres. Area 4 and Area 5, which both drain to Brewer Ditch, total 64.4 and 51.1 acres, respectively. All of Area 4 and Area 5 and a portion of Area 3 were surface mined and reclaimed in the mid-1990s<sup>13</sup>. Those areas will be used as support areas to the surface mining operations.

The recovery of the coal seam requires the excavation of the overlying soil and rock materials, which involves mining through wetlands and streams as the operation advances across the landscape. Sediment basins will be developed as close to the mining area as possible to effectively control sedimentation and surface runoff for the area. Mining and reclamation occur simultaneously as pits are backfilled and resoiled as the next cut is made. The resoiled area is revegetated and returned to the approved post-mining land use. The temporary impacts covered by this permit include coal mining activities tentatively scheduled for 2010 to 2016.

Wetland delineations and stream assessments were conducted by Wetland Services, Inc. from Corydon, Kentucky from September 2008 through June 2009 and January and February 2010 on 82 wetlands and 372 streams within the proposed permit areas. The maximum acreage of jurisdictional wetlands that are planned for disturbance by mining or related activity is 10.42 acres of PFO, 0.80 acres of PSS, 10.85 acres of PEM, and 5.39 acres of PUB. The lengths of jurisdictional streams assessed for impact by mining or related activity are 83,324 linear feet (5.54 acres) of ephemeral streams and 43,362 linear feet (7.55 acres) of intermittent streams. See Map B in Appendix A for the locations of the existing streams and wetlands.

Although these activities qualify it for a Nationwide 21 Permit, we respectfully submit this permit application to the Army Corps of Engineers (ACOE) as an Individual Section 404 Permit.

### 1. **Adjacent Previously Approved Section 404 Permits**

An adjacent Section 404 permit (LRL-2006-1614-gjd), which includes surface coal mining and coal preparation impacts on 4,476.0 acres of the Bear Run Mine (East Pit) f/k/a Farmersburg Mine - Bear Run East Pit, was initially submitted on October 6, 2006 and approved on January 31, 2007. Mitigation has been proposed and approved for all impacts to streams and wetlands and shall adhere to the plan as outlined in Attachment 2 of "Farmersburg Mine - Bear Run East Pit" Section 404 permit application package revised September 14, 2007. This permit abuts the eastern edge of the Bear Run (Amendment 4) project area and is outside of the proposed impacts for this permit.

- B. The **narrative description** should address:

1. Detailed location information.

- a. Directions to the site using road names, highway numbers, and mileage distances.

The permit areas are located east of C.R. 600 East approximately 5.0 miles south of Dugger in Sullivan County, Indiana.

b. Site location map including quarter section, section, township, range and UTM coordinates.

Map A in Appendix A shows the general location of the permit areas. A description of the location of the permit areas are as follows:

Portions of Sections 21, 22, and 33 in Township 7 North, Range 8 West;  
Portions of Sections 3, 10, 11, 14, 15, 22, 23, 26, and 27 in Township 6 North, Range 8 West all in Sullivan County, Indiana

UTM coordinates: X: 474589 Y: 4313580 Zone: 16  
Latitude: N 38.970833°  
Longitude: W 87.293333°  
7.5 Minute Quad: Dugger and Bucktown, Indiana

2. Relative geographic location within USGS 8-digit watershed (e.g., headwater, stream order, floodplain, etc.)

The permit areas are split across two 8-digit watersheds: the Middle Wabash - Busseron (05120111) and the Lower White (05120202). Area 1 and Area 2 drains to Busseron Creek through Buttermilk Creek or Middle Fork Creek. Buttermilk Creek is approximately 2.3 miles north of the Area 1, while Middle Fork Creek flows westerly just outside of Area 2. A large portion of Area 3 drains to the White River either by Pollard Ditch or Brewer Ditch through Black Creek with the remaining portion draining to Maria Creek which is a direct tributary to the Wabash River. Areas 4 and 5 both drain to the Black Creek through Brewer Ditch. The following table summarizes how the permit areas will impact the receiving watersheds.

Watershed Summary										
Receiving Stream <sup>1</sup>	Hydrologic Unit Code <sup>1</sup>	Area in Area 1	Area in Area 2	Area in Area 3	Area in Area 4	Area in Area 5	Total Area in Permit	Percent of Total Area	Receiving Stream Watershed Area <sup>1</sup>	Percent of Total Watershed Area
		(acre)	(acre)	(acre)	(acre)	(acre)	(acre)		(acre)	
Buttermilk Creek	14-digit HUC (05120111160090)	77.8	0	0	0	0	77.8	2.9%	13,364	0.58%
Middle Fork Creek (Sullivan)	14-digit HUC (05120111160120)	7.6	42.3	0	0	0	49.9	1.9%	15,821	0.32%
Maria Creek Headwaters	14-digit HUC (05120111190010)	0	0	342.0	0	0	342.0	12.8%	17,505	1.95%
White River - Pollard Ditch	14-digit HUC (05120202070010)	0	0	1,714.5	0	0	1,714.5	64.3%	17,493	9.80%
Black Creek - Brewer Ditch	14-digit HUC (05120202060020)	0	0	366.8	64.4	51.1	482.3	18.1%	12,799	3.77%
Totals:		85.4	42.3	2,423.3	64.4	51.1	2,666.5	100%	76,982	3.46%
Busseron Creek	11-digit HUC (05120111160)	85.4	42.3	0	0	0	127.7		151,336	0.08%
Maria Creek	11-digit HUC (05120111190)	0	0	342.0	0	0	342.0		62,197	0.55%
Middle Wabash - Busseron	Indiana 8-digit HUC (05120111)	85.4	42.3	342.0	0	0	469.7		718,412	0.07%
Black Creek	11-digit HUC (05120202060)	0	0	366.8	64.4	51.1	482.3		87,870	0.55%
Lower White	8-digit HUC (05120202)	0	0	2,081.3	64.4	51.1	2,196.8		1,070,965	0.21%

3. Surrounding land use:

- a. Percentage of land use type(s) occurring within at least a 1000 ft band of the proposed impact area.

Pre-mine land uses in the permit area are consistent with a rural agricultural and wooded area with a portion reclaimed surface mined area. The major land use is cropland where topography allows, and clearing and improved drainage have been implemented. Forested areas have been limited to low-lying areas along streams and areas where topography does not facilitate agricultural practices. The forests have not been managed for timber production, but do provide wildlife habitat. A portion of Area 3 and the entire acreage of Area 4 and 5 contains land that was previously mined and reclaimed to modern standards. The following table categorizes the pre-mining land uses within the permit area.

Pre-Mine Land Use Summary										
Pre-Mining Land Use	Area 1		Area 2		Area 3		Area 4		Area 5	
	Area	Percent of Area 1	Area	Percent of Area 2	Area	Percent of Area 3	Area	Percent of Area 4	Area	Percent of Area 5
	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Cropland	27.8	32.5			905.9	37.5				
Pasture					131.9	5.4	24.4	37.9		
Forest	32.5	38.1	39.7	93.8	957.9	39.5	25.7	39.9	6.5	12.7
Wildlife	24.0	28.1	2.1	5.0	303.7	12.5	13.0	20.2	14.1	27.6
Water					96.0	4.0			30.5	59.7
Residential	0.6	0.7			7.9	0.3				
Industrial	0.5	0.6			4.2	0.2	0.4	0.6		
Public Roads			0.5	1.2	15.6	0.6	0.9	1.4		
Other					0.2	0.0				
Totals:	85.4	100	42.3	100	2,423.3	100	64.4	100	51.1	100
Natural	85.4	100	42.3	100	1,737.2	71.7	0	0	0	0
Reclaimed	0	0	0	0	686.1	28.3	64.4	100	51.1	100

Post-mine land uses in the permit area will be consistent with the surrounding land uses in the adjacent area. The following post-mine land uses are current as of June 12, 2009 and are subject to change due to property owner waivers and modifications to the mining plan.

Post-Mine Land Use Summary										
Post-Mining Land Use	Area 1		Area 2		Area 3		Area 4		Area 5	
	Area	Percent of Area 1	Area	Percent of Area 2	Area	Percent of Area 3	Area	Percent of Area 4	Area	Percent of Area 5
	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Cropland	27.8	32.5			905.9	37.5				
Pasture					131.9	5.4	24.4	37.9		
Forest	32.5	38.1	39.7	93.8	957.9	39.5	25.7	39.9	6.5	12.7
Wildlife	24.0	28.1	2.1	5.0	383.5	15.8	13.0	20.2	14.1	27.6
Water					16.2	0.7			30.5	59.7
Residential	0.6	0.7			7.9	0.3				
Industrial	0.5	0.6			4.2	0.2	0.4	0.6		
Public Roads			0.5	1.2	15.6	0.6	0.9	1.4		
Other					0.2	0.0				
Totals:	85.4	100	42.3	100	2,423.3	100	64.4	100	51.1	100

- b. Significant land uses(s) within the immediate watershed, which would affect the hydrological inputs or be affected by the hydrological outflows from the proposed impact area (including vegetated buffers/riparian corridors).

Coal mining in the Midwest flattens the existing topography thus lowering runoff velocity that significantly reduces erosion and transport of suspended solids as compared to typical runoff in areas with an agricultural land use. Site reclamation produces topographic relief consistent with the local area and incorporates many erosion control methods such as terracing and dry dam structures to control runoff velocity.

Mining and mine reclamation result in increased water infiltration. If the spoil used for reclamation is highly permeable, the amount of infiltration will be even greater. The infiltrated runoff increases the groundwater storage. Base flow in streams from groundwater will also increase. This extended base flow will improve water quality and offset the short-term effects of reduced shading. Mined overburden functions as a groundwater storage system that slowly releases infiltrated storm water resulting in diminished flooding downstream from storm water runoff.

The process of mining and reclamation typically yields no gain of base flow in higher elevations where the ephemeral streams are generally located. In the lower elevations, actual base flows could be sustained or elongated depending on the permeability of the spoil. Increased base flow allows for functional replacement and enhancement values to the intermittent stream reconstruction. Ephemeral stream mitigation will be located in the higher elevations and flow only during and immediately after precipitation. These streams have by definition no base flow component.

Generally as a result of federal and state regulatory reclamation requirements, reclaimed sites include mitigated wetlands and streams having increased species and habitat diversity, thereby enhancing the ecological function of the area. The additional range of aquatic habitat types (streams, wetlands, and open waters) as a result of reclamation will be an improvement over existing conditions.

#### c. Soils

The *Soil Survey of Sullivan County*<sup>2</sup> maps the following soils within the permit area. The Alford (Af) series consists of deep, well-drained soils located on uplands and formed in loess. Permeability is moderate, surface runoff is medium to rapid, and available moisture capacity is high. The Ava (Al) series consists of deep, moderately well drained soils located on uplands and formed in loess over material weathered from till. A fragipan begins at a depth of 22 to 34 inches. Permeability is slow, surface runoff is slow to medium, and the available moisture capacity is medium. The Cincinnati (Cn) series consists of deep, well-drained soils located on uplands and formed in 10 to 40 inches of loess over weathered loam or clay loam till. A firm, brittle fragipan occurs at a depth of 26 to 32 inches. Permeability is slow, surface runoff is slow to rapid, and the available moisture capacity is medium.

The Cuba (Cu) series consists of deep, well-drained soils located on bottom lands and formed in material washed from upland areas. Permeability is moderate, surface runoff is slow, and the available moisture capacity is high. Gullied land (Gu) occurs on uplands throughout the county. It has moderate to strong slopes. Runoff and erosion are the major hazards. The Hickory (Hk) series consists of deep, well-drained soils located on uplands that formed in a deposit of no more than 20 inches of loess and the underlying material weathered from till. Permeability is moderate, surface runoff is rapid, and the available moisture capacity is high.

The Iva (Iv) series consists of deep, somewhat poorly drained soils that are located on uplands and formed in silty loess. Permeability is slow, surface runoff is slow, and the available moisture capacity is high. The Markland (Ma) series consists of deep, well-drained and moderately well-drained soils that are located on terraces and formed in lacustrine material. Permeability is slow, surface runoff is medium to very rapid, and the available moisture capacity is high. The Muren (Mu) series consists of deep, moderately well-drained soils that located on uplands and formed in silty loess. Permeability is moderate, surface runoff is medium, and the available moisture capacity is high.

The Stendal (Sn) series consists of deep, somewhat poorly drained soils that are located on bottom lands and form in alluvium. Permeability is moderate, surface runoff is slow, and the available moisture capacity is high. The Vigo (Vg) series consist of deep, somewhat poorly drained soils located on uplands and formed in 40 to 60 inches of loess over material weathered from till. A very firm claypan starts at a depth of 18 to 24 inches. Permeability is very slow, surface runoff is slow, and the available moisture capacity is high.

The Wakeland (Wa) series consist of deep, somewhat poorly drained soils that are located on bottom lands and formed in alluvium. Permeability is moderate, surface runoff is slow, and the available moisture capacity high. The Wilbur (Ww) series consists of deep, moderately well drained soils that are located on bottom lands and formed in alluvium. Permeability is moderate, surface runoff is slow, and the available moisture capacity is high. A soil type labeled as Reclaimed (-) comprises approximately a quarter of the south area. This designation is applied to areas that contain soils that have been disturbed for the reclamation of coal mining operations. The thickness of the soil on top of the spoil varies from 1 to 4 feet in depth. The composition of the reclaimed soil also varies due to the mixing of the native soils as they were stripped off and stockpiled prior to the mining operation. Finally, water (W) is also located in the permit area.

The following table lists the soils and their acreages for each permit area and Map WS in Appendix A displays the soil type boundaries. In addition to the soil boundaries on the map, there are shaded areas that represent potentially hydric soils. None of the soils within the permit area are listed on the Indiana Hydric Soils List<sup>5</sup>, but there are several soils that are located in bottom lands and have high moisture capacity which indicate these soils have the potential to easily turn hydric or have hydric inclusions. Within the permit area, the potentially hydric soils are the Cuba, Stendal, Wakeland, and Wilbur soil series. Area 2 has ~9.5 acres and Area 3 has ~113.8 acres of potentially hydric soils.

Soil Summary												
Soil Series	Map ID	Area 1		Area 2		Area 3		Area 4		Area 5		Slope
		Area	Percent of Area 1	Area	Percent of Area 2	Area	Percent of Area 3	Area	Percent of Area 4	Area	Percent of Area 5	
		(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)			(%)	
Alford	AfB2					5.7	0.2					2 - 6
	AfB3					1.3	0.1					2 - 6
	AfC3					2.1	0.1					6 - 12
	AfD2					1.0	0.0					12 - 18
	AfD3					2.4	0.1					12 - 18
	AfF					0.9	0.0					
Ava	AIA					11.8	0.5					0 - 2
	AlB2	32.6	38.2	14.5	34.3	395.1	16.3					2 - 6
	AlB3	9.5	11.1			69.8	2.9					2 - 6
Cincinnati	CnB2			0.4	0.9	177.0	7.3					2 - 6
	CnC2					32.5	1.3					6 - 12
	CnC3	25.7	30.1	1.1	2.6	329.3	13.6					6 - 12
	CnD2			2.9	6.9	55.9	2.3					12 - 18
	CnD3	7.4	8.7	2.1	5.0	123.2	5.1					12 - 18
Cuba	Cu			9.5	22.4	0.6	0.0					
Gullied land	Gu					27.2	1.1					strong
Hickory	HkE	9.8	11.5			82.5	3.4					18 - 25
	HkF			11.6	27.4	19.8	0.8					25 - 35
	HkF3	0.2	0.2	0.2	0.5	45.6	1.9					25 - 35
Iva	IvA					1.9	0.1					0 - 2
Muren	MuB2					3.9	0.2					2 - 6
Stendal	Sn					6.8	0.3					
Vigo	VgA	0.2	0.2			123.4	5.1					0 - 2
	VgB2					12.7	0.5					2 - 4
Wakeland	Wa					36.9	1.5					
Wilbur	Ww					71.9	3.0					
Reclaimed	-					686.1	28.3	64.4	100	20.6	40.3	
Water	W					96.0	4.0			30.5	59.7	
Totals:		85.4	100	42.3	100	2,423.3	100	64.4	100	51.1	100	

Source: *Soil Survey of Sullivan County*<sup>2</sup>

There are approximately 15.2 acres of prime farmland in Area 1 and 517.1 acres in Area 3 for a total of 532.3 acres.

4. Classification:

a. Wetlands:

- i. Hydrogeomorphic subclass and "first principles, or
- ii. Cowardin classification, and,
- iii. Landscape setting

Wetland delineations were completed by Wetland Services, Inc. on a total of 80 jurisdictional and 2 isolated wetland areas within the permit area utilizing the 1987 Corps of Engineers Wetland Delineation Manual<sup>4</sup> along with the Cowardin classification method. The delineations that were conducted in January-February 2010 utilized the Midwest Regional Supplement<sup>28</sup>. Representative determination points were selected within the small (<5 acre) area potential wetland sites and baseline establishment along with transects were selected within the larger (>5 acre) area potential wetland sites. Field observations and sampling were focused by distinct and often abrupt change in vegetative communities. Dominant vegetation for represented strata was noted, along with any evidence of wetland hydrology present at each determination point. Soil probes were examined for hydric soil characteristics. Soil matrix and mottle chroma were referenced from the Munsell Soil Color Chart. Delineation boundaries were established and flagged at the transition from field indicated non wetland - wetland sites based on vegetative, soil, and hydrological criteria at representative sample points. Delineation boundaries were extended between sample locations by following lines of distinct vegetation and hydrology while confirming soils conditions with periodic probing. See Appendix C for detailed wetland delineations and summary table and Map B in Appendix A for their locations.

b. Streams:

- i. Rosgen stream classification method, or
- ii. Strahler order classification method, and
- iii. Flow regime (ephemeral, intermittent, perennial)

Streams assessments were conducted by Wetland Services, Inc. utilizing a modified Rosgen stream classification method and the USEPA Rapid Bioassessment Protocols (RBP)<sup>29</sup> [for habitat assessment](#).

Typically, the Rosgen stream classification method is used to predict what adjustments a stream needs to achieve stability, which is the ability of a stream to transport sediment, in the present climate and streamflow regime to maintain dimension, profile, and pattern without aggrading or degrading. Because the stream mitigation for coal mining is predominately stream relocation rather than stream channel restoration, a modified Rosgen stream classification has been utilized in classifying the pre- and post-mining streams. This has been an ACOE accepted method for the low gradient streams in southern Indiana and Illinois. Level I, II, and III Rosgen stream parameters are visually assessed in the field and recorded on the stream assessment sheets along with photographs of the assessment point.

A total of 323 stream assessments were made with 254 classified as ephemeral and 69 classified as intermittent. See Appendix B for a summary table of stream assessments and the detailed geomorphic assessment with photographs, and Map B in Appendix A for the assessment locations.

There are several clarifications concerning the stream assessment worksheets that are being made at the request of the Louisville District West Section. These include the: 1) Missouri Stream Mitigation Method functionality parameters 2) Altered Channel Key and 3) Riparian Vegetation width.

The stream assessment worksheets that were developed from surveys completed from September 2008 to June 2009 include functionalities as ranked by the ACOE's Missouri Stream Mitigation Method. This method is not recognized by the Louisville District West Section as an appropriate mitigation method and therefore should not be considered when determining stream functionality associated with this application. The stream assessment worksheets completed or modified in January and February 2010 do not include Missouri Stream Mitigation Method functionality parameters.

The stream assessment worksheets that were developed from surveys completed from September 2008 to June 2009 include Altered Channel descriptions that have been removed, at the request of the Louisville District West Section, from the stream assessment worksheets completed or modified in January and

February 2010. The descriptions that have been removed are: AG = Agriculture, CC = Clear Cut, LS = Limestone Channel, MNG = Disturbed by Mining, RC = Road/Culvert Crossing, SE = Sewage, RCD = Rock Check Dam, RL = Recent Logging, RSD = Road Side Ditch, RSS = Road Side Stream, WD = Weir Dam and TR = Trash & Debris. These were replaced with: CV = Culvert, DAM = Weir, Dam, or Rock Checks, LWC = Low Water Crossing, NA = Not Applicable, OT = Other (See Comments), PI = Pipe and RSC = Road Side Channel. The most significant change concerns the deletion of the AG = Agriculture description. The original intent was to show that these streams may not have been directly (physically) altered for agriculture, but have been indirectly altered due to the increase sediment load, fertilizers and pesticides that have been transported from adjacent agricultural fields into the streams and by the drop in base level (head cutting) from downstream channelization.

As discussed with the Louisville District West Section, the Riparian Vegetation widths that are noted on the stream assessment worksheets may not represent the width of a defined 'riparian buffer' associated with each stream assessment. Wetland Service, Inc., who performed the assessments, recorded the type of adjacent riparian vegetation using the alpha-numeric descriptor from the noted methods as described by Dave Rosgen. The width was determined by visually assessing the distance the vegetation extended away from the stream regardless if the widths extended across watershed breaks. This method resulted in vast widths of upland vegetation being included and line of sight overlaps as streams converged at confluences. Overlaps are most evident in the wooded areas. For example, a deciduous overstory width of 200+ feet was recorded for both the right and left banks of Stream A. A width of 200+ feet means that the field delineator determined that trees extended as far as their line of sight allowed regardless of drainage breaks. Stream B parallels Stream A, by a stream centerline offset of 150 feet, in an adjoining valley. Stream B has also been determined by the field delineator to have a deciduous overstory width of 200+ feet for both the right and left banks, which results in an overlap of 125 feet for both streams. It should also be stressed that Wetland Services intent was to measure adjacent vegetation and not determine what may constitute a 'riparian buffer', the definition of which varies widely throughout sources of scientific and non-scientific literature.

Stream habitat evaluations were conducted using the USEPA Rapid Bioassessment Protocols (RBP)<sup>29</sup> and included on a compact disk in Appendix K. The streams at the Bear Run (Amendment 4) area are classified into four groups based on flow regime: ephemeral and intermittent and setting: natural and reclaimed. The following table summarizes the RBP scores from the [Habitat Assessment Field Data Sheets](#) for the four groups with addition classification by stream gradient.

Summary of RBP Scores					
Setting	Flow Regime	Gradient	Minimum Score	Maximum Score	Median Score
Natural	Ephemeral	Low Gradient	61	114	96
		High Gradient	60	127	95
Reclaimed	Ephemeral	Low Gradient	74	110	88
		High Gradient			81*
Natural	Intermittent	Low Gradient	76	129	102
		High Gradient	75	100	93
Reclaimed	Intermittent	Low Gradient	84	102	94
		High Gradient			**

\*Denotes one high gradient reclaimed ephemeral stream assessed

\*\*Denotes no high gradient reclaimed intermittent streams were assessed

Existing scores ranged from 60 to 127 in the upstream (high gradient) streams and 61 to 129 in the downstream (low gradient) portions. The natural ephemeral streams generated a higher median score than the reclaimed ephemeral streams primarily due to their having greater riparian vegetative widths and more vegetation established on the banks. The low score was obtained on Stream 8NS1K3-1 with the

high score obtained on Stream 4NS33. Stream 8NS1K3-1 is an ephemeral stream located in an agricultural field which has no riparian vegetation and very unstable banks. Stream 4NS3, which is a headwater stream located in the Maria Creek watershed, has stable banks, established vegetation on the banks, wide riparian buffer, and a natural pattern with no evidence of channelization or dredging.

The natural and reclaimed intermittent streams have comparable median habitat scores that vary from 93 to 102. The reclaimed intermittent streams scored higher due to the low number of samples. The low score was obtained on Stream 8NS1K3 with the high score generated from Stream 4NS14-16. Stream 8NS1K3 is immediately downstream of Stream 8NS1K3-1 (the low score ephemeral). Stream 4NS14-16 is a low gradient stream with stable banks and established vegetation on the banks.

c. Open Water:

Open water assessments were conducted by Wetland Services, Inc. to determine if the water body is isolated or jurisdictional, as well as the intended use. A total of 15 open water assessments were made. The waters are utilized for a wildlife or recreational purpose. Several of the large open waters in Area 3 of the permit are final cut impoundments from previous mining operations. See Appendix C for photographs and see Map B in Appendix A for locations.

d. Unit ID Labeling System:

Wetland Services, Inc. has developed a watershed approach in labeling the streams, wetlands, and open waters that are assessed within a permit area. A watershed has been defined as any stream that leaves the permit boundary on its own accord. For accurate record-keeping purposes, a unit specific labeling system has been developed as shown by the example below.

1NS2A1-1 = Unit ID

1 = Watershed (any single stream that leaves the permit boundary)

N = Land use (Natural, Reclaimed, Pre-law, Agriculture, Mixed, Logged, or Excavated)

S = Unit type (Sream, Wetland, Open Water)

2 = Unit number (2<sup>nd</sup> stream assessed in watershed 1)

A = 1<sup>st</sup> branch of stream 2

1 = 1<sup>st</sup> branch of stream 2A

-1 = Subsequent assessment on stream 2A1

5. Existing conditions: Landscape Setting/Ecosystem Context

- a. Wetlands: Briefly describe the physical setting of the site, including, but not limited to adjacent land uses, ecological types, topography, buffers, and hydrogeomorphic features. Provide information on type of soil present (include hue, value and chroma for each soil horizon) and soil series.

The wetland delineation survey identified 80 areas that met jurisdictional criteria. None are located in the Area 1 or Area 5. There are 4 jurisdictional wetlands located in Area 2 and Area 4, with the remaining wetlands located in Area 3.

Wetlands located in a natural setting were found in poorly drained areas along streams or around the fringe of open waters. Wetlands in a reclaimed setting that are not located around open waters have developed from the differential settling of the reclaimed soil. Reclaimed soils were placed in these areas with intense compaction which developed a shallow impermeable layer that has resulted in perched water tables throughout the reclaimed area producing a "pothole" community. Because the soils were homogenized during the mining process, any given sample of brown upland soil may contain low-chroma mottles. In dry areas, these mottles are derived from deep calcareous parent material brought up during the mining process and have no relevance to hydric soil development. In wet areas, mottling is a combination of ancient low-chroma parent material and the result of recent intense reducing conditions. Hydric inert calcareous material is readily distinguished by texture and structure and is subsequently disregarded. The wetlands range in size from 0.01 acre to 3.47 acres with an average size of 0.34 acre.

The following tables summarize the acreage and classification of the wetlands found within the permit areas. Please see Appendix C for detailed wetland delineations and Map B in Appendix A for the location of the wetlands.

Wetland Summary				
Setting	PFO	PSS	PEM	PUB
	(acre)	(acre)	(acre)	(acre)
<b>Jurisdictional Natural</b>				
Area 1	0	0	0	0
Area 2	0.47	0.53	0	0
Area 3	7.98	0	0.96	0.53
Area 4	0	0	0	0
Area 5	0	0	0	0
Natural Totals:	8.45	0.53	0.96	0.53
<b>Jurisdictional Reclaimed</b>				
Area 1	0	0	0	0
Area 2	0	0	0	0
Area 3	1.96	0.27	7.54	4.58
Area 4	0	0	2.35	0.28
Area 5	0	0	0	0
Reclaimed Totals:	1.97	0.27	9.89	4.86
Jurisdictional Totals:	10.42	0.80	10.85	5.39
<b>Non-Jurisdictional Natural</b>				
Area 1	0	0	0	0
Area 2	0	0	0	0
Area 3	0	0	0	0
Area 4	0	0	0	0
Area 5	0	0	0	0
Natural Totals:	0	0	0	0
<b>Non-Jurisdictional Reclaimed</b>				
Area 1	0	0	0	0
Area 2	0	0	0	0
Area 3	0	0	0.17	0
Area 4	0	0	0	0
Area 5	0	0	0	0
Reclaimed Totals:	0	0	0.17	0
Isolated Totals:	0	0	0.17	0

b. Streams:

- i. Describe site geomorphology (Channel pattern, profile, and dimension), substrate particle size distribution, canopy cover, riparian vegetation structure and complexity, hydrology/flow regime(s), channel habitat types (e.g. percentage of reach composed of pools, riffles, etc.).
- ii. Also describe stream functions such as, but not limited to, hydrology (i.e. efficient dissipation of energy) and biochemical processes (i.e. denitrification as indicated by presence of beds of organic matter).
- iii. Landscape setting

The streams within the permit are physically differentiated by being located in a natural setting or in a reclaimed mining area. The streams to be impacted are predominately headwater ephemeral streams and low to moderate quality intermittent streams in the natural area and constructed or gullied areas in the reclaimed areas.

The following table summarizes the stream impacts for the permit areas. The summary tables in Appendix B display specific data for the individual streams.

Stream Summary				
Setting	Ephemeral		Intermittent	
	(linear feet)	(acre)	(linear feet)	(acre)
<b>Jurisdictional Natural</b>				
Area 1	4,576	0.26	2,790	0.24
Area 2	1,197	0.10	2,358	0.66
Area 3	75,260	5.05	37,442	6.54
Area 4	0	0	0	0
Area 5	0	0	0	0
Natural Totals:	81,033	5.41	42,590	7.44
<b>Jurisdictional Reclaimed</b>				
Area 1	0	0	0	0
Area 2	0	0	0	0
Area 3	2,291	0.13	772	0.12
Area 4	0	0	0	0
Area 5	0	0	0	0
Reclaimed Totals:	2,291	0.13	772	0.12
<b>Jurisdictional Totals:</b>				
	83,324	5.54	43,362	7.55

The following summary table shows the anticipated impacts by to the stream broken down by land use setting and flow regime. Effects to the waters were categorized into four primary types that occur at a surface coal mining operation: coal extraction activities (mine-through), spoil placement, sediment basins, and sediment/drainage control and support. [Sediment/drainage control and support areas include soils stockpiles, berms, collection/diversion ditches, parking lots, buildings, freshwater return lakes, haul roads, etc., basically any area outside of the mining line and spoil placement areas.](#) These effects are based on the currently approved operations map, which is subject to minor change as mining commences.

Impact by Effect Summary					
Setting	Flow Regime	Coal Extraction Activities	Spoil Placement	Sediment Basins	Sediment/ Drainage Control and Support
		(feet)	(feet)	(feet)	(feet)
Jurisdictional					
Natural	Ephemeral	74,950	2,725	810	2,548
Reclaimed	Ephemeral	983	1,161	0	147
Ephemeral Totals:		75,933	3,886	810	2,695
Natural	Intermittent	37,698	844	2,811	1,237
Reclaimed	Intermittent	0	299	0	473
Intermittent Totals:		37,698	1,143	2,811	1,710

Adjacent Vegetation Total Width Summary					
Setting	Flow Regime	No Adjacent Vegetation	0 to 10' Adjacent Vegetation	10' to 50' Adjacent Vegetation	> 50' Adjacent Vegetation
		(feet)	(feet)	(feet)	(feet)
Jurisdictional					
Entire Area	All Flow	6,594	0	5,415	114,667

See Map B in Appendix A for the locations of the existing streams and see the stream assessments in Appendix B for more detailed site information.

Overall, the site has been heavily impacted by almost two hundred years of anthropogenic activity. In 1896, a state ditching law was passed that manipulated the watersheds of Sullivan County. This law provided more of a benefit than just improving the lands for purposes of agriculture. It removed the stagnant pools and swamps that harbored insects that carried once deadly, but now treatable diseases<sup>25</sup>. The early settlers impacted the watersheds with extensive and ambitious ditches designed to increase drainage for farming, thereby initiating the first extensive siltation. The principal source of channelizing the larger floodplain perennial streams was the ACOE or other government funded or subsidized projects. This activity resulted in head cutting or "headcut creep" of connecting intermittent and ephemeral streams. This process generally occurs swiftly in the floodplain regions due to massive amounts of pooled floodwaters rapidly exiting the floodplain. The headcut creep then slows but continues up gradient. This process ultimately entrenches even the smallest of streams and in many cases creates erosional features that would have not existed in an undisturbed ecosystem. The steeper gradient caused by dredging combined with other anthropogenic headwater activities (agricultural, livestock, logging, etc.) has negatively impacted a substantial portion of the onsite streams.

The site has been moderately impacted by previous mining activities. According to the Indiana Geological Survey - Coal Mine Information System<sup>13</sup>, the previously mined area adjacent to and included in Area 3, Area 4, and Area 5 was mined by the Hawthorn Mine. The Hawthorn Mine was in operation from 1965 to 1999. The reclamation in accordance with SMCRA focused on erosion and sediment control which resulted in the construction of terraces, swales, and water and sediment control basins (WASCOBs). These sediment and erosion control structures trapped sediment and runoff, reducing flooding and gully erosion, and improving the farmability of a field. Riprap was also used to line stream bottoms and sides to prevent erosion in the constructed ditches. Most of the reclaimed previously mined land use intermittent streams in the Bear Run (Amendment 4) area, were built to facilitate runoff from the area. Several of the reclaimed previously mined land use ephemeral streams are either gullies that have formed from baseline adjustment through head cutting or gullies that have formed in rills down unstable slopes.

Additionally, from a visual survey of the permit area, approximately 18 percent of all the streams flow into an open water before continuing on in the watershed. For each of the individual permit areas, the following is a breakdown of the stream lengths that flow into open waters.

Stream Through Open Water Summary		
Setting	Ephemeral	Intermittent
	(linear feet)	(linear feet)
Area 1	0	0
Area 2	0	0
Area 3	21,082	8,157
Area 4	0	0
Area 5	0	0
Totals:	21,082	8,157

Area 1 does not have any streams that flow immediately into an open water body. All of the streams in Area 2 flow into an open water (the impoundment on Middle Fork Creek), located west of the permit area. Area 3 contains streams that flow into open waters consisting of final cut impoundments that were reclaimed once mining was completed. There is one open water in the natural area that appears to have been constructed for flood control (Open Water 9N011). The length of streams that flow into open waters is approximately 21,852 linear feet or 18.4 percent of the total stream in the permit areas.

c. Open Waters:

Several small water impoundments and farm ponds are present in the natural area of the permit. These impoundments are small due to their watershed size and permeability of the surrounding soils and were constructed for primarily an agricultural land use. These farm ponds have been abandoned and are now wildlife habitat. Open waters with a wildlife land use are present in the reclaimed areas of the permit

area on a larger scale than the natural areas. These open waters may be reclaimed sediment basins or final cut lakes. The following table summarizes the open waters. See Map B in Appendix A for their locations and Appendix C for any photographs.

Open Water Summary		
Setting	Acreage	Comments
	(acre)	
<b>Jurisdictional Natural</b>		
Area 1	0	
Area 2	0	
Area 3	4.38	
Area 4	0	
Area 5	0	
<b>Natural Totals:</b>	<b>4.38</b>	
<b>Jurisdictional Reclaimed</b>		
Area 1	0	
Area 2	0	
Area 3	107.55	
Area 4	0	
Area 5	0	
<b>Reclaimed Totals:</b>	<b>107.55</b>	
<b>Jurisdictional Totals:</b>	<b>111.93</b>	
<b>Non-Jurisdictional Natural</b>		
Area 1	0	
Area 2	0	
Area 3	0	
Area 4	0	
Area 5	0	
<b>Natural Totals:</b>	<b>0</b>	
<b>Non-Jurisdictional Reclaimed</b>		
Area 1	0	
Area 2	0	
Area 3	0	
Area 4	0	
Area 5	34.54	Covered by NPDES permit
<b>Reclaimed Totals:</b>	<b>34.54</b>	
<b>Non-Jurisdictional Totals:</b>	<b>34.54</b>	

- Field observations (e.g. for wetlands use data sheets from the "Corps of Engineers Wetland Delineation Manual," Technical Report Y-87-1 or for streams use data sheets from EPA's Rapid Bioassessment Protocol, and show the location of the data points on a site map)

See the wetland delineations in Appendix C and the stream assessments in Appendix B for the field observations. Map B in Appendix A shows the location of the assessment points and boundaries.

- Climate (This component should address normal circumstances as described in TR Y-87-1, including local and regional variability and extremes)

The permit area is located in Sullivan County, Indiana, which exhibits a continental climate influenced by cold polar air from the north and warm air from the south. The average annual rainfall is approximately 39 inches. Average annual runoff is approximately 12 inches. Precipitation is generally greatest in the late spring and early summer with an average cumulative precipitation slightly over 4 inches per month.

During the fall and winter seasons the average cumulative precipitation is less than 3 inches per month. The 24-hour precipitation event for the area ranges from 2.7 inches for a one year frequency event to 5.1 inches for a 25-year frequency. Two-hour rainfall intensity ranges from 1.5 inches for a one-year frequency to 2.9 inches for a 25-year frequency. In general, the highest mean monthly stream flows in southern Indiana occur from March through May when spring rains occur; the highest peak flows are typically in July as a result of thunderstorm activity.

The mean annual surface air temperature is approximately 53°F. July is usually the warmest month (~77°F) and January is usually the coldest (~31°F). Evapotranspiration is estimated to average approximately 27 inches annually. Maximum evapotranspiration typically occurs during June or July and the minimum is during December or January. Prevailing winds are typically from the southwest with an average velocity of 10 mph in the spring and 7 mph in late summer, except during the winter when they are westerly and northwesterly.

8. Water Quality (e.g. denitrification, conductivity, pH); identify any state listed CWA Section 303(d) impaired waterbodies within the watershed.

There are three 303(d) listed waters that are found within the immediate watersheds of the permit area. They are Buttermilk Creek (INB11G9\_00), Maria Creek Headwaters (INB11K1\_01), and Black Creek-Brewer Ditch (INW0262\_00). For more details of the areas assessed and types of impairments, please refer to *Item 13. Cumulative Activity* on pages 20-21.

The following tables list the regional surface water quality as found in U.S. Geological Survey Open-File Report 81-498<sup>7</sup> for Area 32 which includes the White River watershed and U.S. Geological Survey Open-File Report 82-1005<sup>12</sup> for Area 30 which includes the Wabash River watershed.

Area 32 (White River) Regional Surface Water Quality <sup>7</sup>			
Parameter	Range	Median	Number of Stations
pH	2.4 - 8.9	7.4	293
Specific Conductance (µmhos /cm)	39.5 - 8,960	615	286
Sulfate (mg/l)	2.4 - 6,230	65	145
Total Iron (mg/l)	0.03 - 2,300	1.3	100
Total Manganese (mg/l)	0.01 - 33	0.62	98

Area 30 (Wabash River) Regional Surface Water Quality <sup>12</sup>			
Parameter	Range	Median	Number of Stations
pH	2.5 - 9.0	7.8	159
Specific Conductance (µmhos /cm)	90 - 4,920	623	159
Sulfate (mg/l)	20 - 3,379	69	134
Total Iron (mg/l)	0.09 - 1,200	0.95	114
Total Manganese (mg/l)	0.01 - 14.6	0.20	111

The following table lists the local surface water quality from baseline monitoring sites for the permit area. The locations of the sites are found on Map A in Appendix A.

Local Surface Water Quality <sup>8</sup>						
Parameter	21SW-N1		33SW-1		16SW-S5	
	Range	Mean	Range	Mean	Range	Mean
pH	7.24-7.52	7.38	7.58-7.91	7.75	7.75-7.80	7.78
TDS (mg/l)	259-298	279	263-344	300	201-274	238
Alkalinity (mg/l)	82-94	88	94-116	102	66-104	85
Total Iron (mg/l)	0.10-0.36	0.23	0.16-0.29	0.22	0.11-0.18	0.15

Total Manganese (mg/l)	0.10-0.20	0.15	0.43-1.24	0.83	0.04-0.05	0.05
Parameter	21SW-S7		28SW-S8		27SW-S13	
	Range	Mean	Range	Mean	Range	Mean
pH	7.56-7.67	7.62	7.83-7.86	7.85	7.74-7.65	7.70
TDS (mg/l)	225-327	276	152-250	201	182-229	206
Alkalinity (mg/l)	72-110	91	56-148	102	72-94	83
Total Iron (mg/l)	0.30-0.59	0.45	0.32-0.33	0.33	0.21-0.23	0.22
Total Manganese (mg/l)	0.11-0.23	0.17	0.06-0.06	0.06	0.06-0.12	0.09

#### Surface Water Sampling Plan for Streams and Wetlands

In addition to the baseline surface water quality data provided above, surface water samples will be collected from proposed sites and analyzed to further characterize water quality before (pre-mining) and after (post-mining) mitigation has been completed. Water sampling will be conducted at the following:

- SMCRA receiving stream sampling points
  - pH
  - Total dissolved solids
  - Alkalinity
  - Total iron
  - Total manganese
- Internal stream/wetland water quality sampling points
  - pH
  - Total dissolved solids
  - Total iron
  - Total manganese
- Bio-assessment sampling points
  - Temperature
  - Total dissolved solids
  - pH
  - Total iron
  - Total manganese

SMCRA receiving stream and Internal stream/wetland water quality sampling (pre- and post-mining) will be conducted on a quarterly basis to ensure adequate flow and representative water quality. Bio-assessment surface water sampling will be conducted annually. Pre-mining sample sites are located on Map G and post-mining sample sites are located on Map H.

9. Identify the Functional Assessment Tool that will be used to measure the development of the mitigation site and ultimately the successful compensation of lost function and value from the permitted impact.

#### Wetlands

The functional assessment tools that will be utilized to measure the successful development of the wetland mitigation are the Corps of Engineers Wetland Delineation Manual<sup>4</sup> and the Midwest Regional Supplement<sup>28</sup>. The wetlands will also be monitored yearly for positive trends using certain variables of the Corps of Engineers Hydrogeomorphic Method (HGM). Wetland success will be achieved by establishing an area that not only has wetland hydrology, hydric soils, and hydrophytic vegetation, but is also self-sustaining.

#### Streams

The functional assessment tools that will be utilized to measure the successful development of the stream mitigation include one based on the Rosgen<sup>3</sup> stream channel matrix as developed by Dave Rosgen and the USEPA Rapid Bioassessment Protocols (RBP) utilizing the Habitat Assessment Field Data Sheets for physical characterization and habitat. Stream success is achieved by establishing a natural stream channel that has a stable cross-section, stable meander pattern, and a stable profile such that over time, the stream channel features and stability are maintained.

The following table lists the types of channels that will be used in mitigation. The specific type will be dependent on the reclaimed slope of the stream and watershed size.

Rosgen Channel Morphology Matrix				
Stream Type	A	B	C	E
Bed Material and Designation	Silt-Clay (6) Sand (5) Gravel (4)	Silt-Clay (6) Sand (5) Gravel (4)	Silt-Clay (6) Sand (5) Gravel (4)	Silt-Clay (6) Sand (5) Gravel (4)
Entrenchment Ratio	<1.4	1.4-2.2	>2.2	>2.2
Width/Depth Ratio	<12	>12	>12	<12
Sinuosity	1.0-1.2	>1.2	>1.2	>1.5
Slope (percent)	4-10	2-3.9	<2	<2

The term "entrenchment ratio" is the vertical containment of the stream. It is the ratio of the width of the flood-prone area to the surface width of the bankfull channel. The flood-prone area is determined by using the elevation of twice the maximum depth of the bankfull channel at bankfull stage. The width/depth ratio is defined as the ratio of the bankfull surface width to the mean depth of the bankfull channel at bankfull stage. This ratio is used to describe the energy and ability of various discharges to move sediment. It is also valuable for describing the channel cross-section shape. Sinuosity is the ratio of stream length to valley length. Meander geometry characteristics are directly related to sinuosity.

#### 10. Geology

The proposed permit area consists of approximately 2,666.5 acres of rural forested, agricultural, and previously mined land located on the eastern shelf of the Illinois Basin in the Wabash Lowland physiographic province. The permit consists of five separate subareas: Area 1 is 85.4 acres, Area 2 is 42.3 acres, Area 3 is 2,423.3 acres, Area 4 is 64.4 acres, and Area 5 is 51.1 acres. Approximately 30 percent of the proposed permit area has been previously disturbed and reclaimed as a result of surface mining and related activities. These activities occurred in Area 3, Area 4, and Area 5. Natural landforms are the result of both Illinoian glaciation and normal degradation processing such as weathering, mass wasting, and stream erosion. The topography is characterized by generally flat ridge tops with moderately steep side slopes and broad, flat valley floors. The surface drainage pattern is dendritic, reflecting the horizontal regional bedrock structure. The maximum topographic relief of the site is approximately 130 feet, ranging from 470 feet to 600 feet above mean sea level. See Map A in Appendix A for a general reference of the permit area.

##### a. Unconsolidated materials

In the natural (un-mined) areas of the permit, a layer of unconsolidated earthen material exists between the soil layer and the bedrock surface. This unconsolidated layer typically ranges from 11 to 100 feet in thickness. It is the basic parent material of the overlying soil layer. This intermediate layer may contain blocks of consolidated rock that have become detached from the underlying bedrock surface. This intermediate layer of unconsolidated material is thought to represent till that was deposited between 140,000 and 300,000 years ago during the Illinoian glacial period and loess deposits. The Quaternary glacial till is composed of earth material that has been kneaded, pulverized, and transported by the glacier, potentially from areas up to hundreds of miles to the north. Bedding within the till zone is complex because of the multiple episodes of erosion and transport that occurred before its final deposition. Site-specific drill logs indicate that the bulk of the unconsolidated zone is composed of unsorted silty clay of variable thickness. Distinct lenses of sand and sand/gravel occur sporadically within this matrix. These lenses probably represent buried stream channels created by waters from melting ice or by storm events during and immediately after Illinoian time. The unconsolidated layer typically thins toward the uplands and thickens toward the valleys.

In the reclaimed areas of the permit, the unconsolidated layer between the soil and the bedrock surface is comprised of mine spoil. Mine spoil is composed of Quaternary unconsolidated material, fragmented bedrock, and coal. This material varies in thickness and composition through the reclaimed permit area.

b. Bedrock

The Pennsylvanian overburden interval to be disturbed by surface mining consists of the Lower Shelburn, Dugger, and Upper Petersburg Formations. These strata consist of cyclic sequences of shale, sandstone, limestone, and coal units associated with fluctuating shoreline environments of the Pennsylvanian Period. Such strata can be highly variable in thickness and continuity. The regional dip for Pennsylvanian rocks is to the southwest at a rate of approximately 25 feet per mile. Mississippian-aged rocks unconformably underlie the Pennsylvanian section. However, Mississippian rocks do not outcrop locally and were not penetrated during exploratory drilling.

The Indiana No. 7, No. 6, No. 5A, and No. 5 Coal seams are the seams targeted for extraction. Minor and/or thinly-bedded coal exists sporadically above the No. 7 seam, including the Pirtle and Ditney seams. The Ditney seam is a thinly-bedded, sporadically occurring bituminous coal seam, described by the Indiana Geological Survey as a banded, partly shaly coal, generally less than 1.0 foot thick. The Pirtle seam, also known as No. 7A Coal, is a thinly-bedded, sporadically occurring bituminous coal seam that is described as bright, banded, and shaly in places and ranges between 0 to 1.02 feet in thickness. These minor seams are generally considered to be of insufficient quality or thickness for economic extraction. Any coal not extracted for sale as a fuel resource will be handled as toxic overburden when possible. However, in the areas where any coal seam exhibits suitable thickness and quality, the applicant will attempt to recover said resource.

The No. 7 seam, according to the Indiana Geological Survey, is as a bright, banded, bituminous coal, containing thin partings of clay and shale, with films of clay in vertical joints, and local concentrations of pyrite and marcasite. The mean thickness of the No. 7 seam within the proposed amendment area is about 2.8 feet.

The No. 6 seam is described by the Indiana Geological Survey as a bright, banded, bituminous coal containing shale and pyrite partings. The mean thickness of the No. 6 seam within the proposed amendment area is about 3.7 feet.

The No. 5A Coal seam is described by the Indiana Geological Survey as a coal seam occupying the stratigraphic position between the top of the Alum Cave Limestone and the base of the Antioch Limestone. The No. 5A Coal seam ranges between 0 and 4.1 feet, and averages about 2.9 feet in thickness where present.

The No. 5 seam is described by the Indiana Geological Survey as a bright coal that duffs upward. The mean thickness of the No. 5 seam within the proposed amendment area is approximately 3.9 feet. The No. 5 seam will be the lowest coal seam to be mined within the proposed amendment area.

The following stratigraphic column is based upon Peabody Midwest Mining, LLC drill logs within the permit area:

Summary of Stratigraphy <sup>8</sup>		
Thickness Range (feet)	Average Thickness (feet)	Lithology
5.50 - 33.00		drift, sand with gravel, sandstone boulder, silt with gravel, silty to sandy clay, unconsolidated
0 - 50.00		black shale, limestone, sandstone, sandy shale, shale
0 - 0.75		Ditney Coal
0 - 68.31		limestone, limey sandstone, limey sandy shale, limey shale, sandstone, sandy shale, shale, shaly limestone, underclay
0 - 1.02		Pirtle Coal
0 - 118.60		coal, limestone, limey sandstone, limey sandy shale, limey shale, sandstone, sandy limestone, sandy shale, shale, underclay

0 - 4.04	2.8	Indiana No. 7 Coal
0 - 46.70		black shale, coal, limestone, limey sandstone, limey shale, sandstone, sandy shale, shale, underclay
0 - 9.45	3.7	Indiana No. 6 Coal
0 - 53.30		black shale, coal, limestone, limey sandstone, limey sandy shale, limey shale, sandstone, sandy limestone, sandy shale, shale, shaly limestone, underclay
0 - 4.10	2.9	Indiana No. 5A Coal
13.70 - 44.39		black shale, limestone, limey sandy shale, limey shale, sandstone, sandy shale, shale, shaly coal, shaly limestone, underclay
2.50 - 5.20	3.9	Indiana No. 5 Coal
???		sandstone, sandy shale, shale, underclay

The thickness ranges are based on a finite number of bore holes as represented by the Geologic Cross-Section found in the SMCRA mining permit S-00256-4. The average thickness is based on an expanded data base SurvCAD computer model of the geologic data across the permit area.

#### c. Geochemistry of Bedrock

No problems are expected from toxic (acidic) materials found at the site. Any such materials will be placed low in the spoil profile to eliminate potential oxidation. Placement will occur concurrently with the planned extraction and reclamation operations.

#### d. Aquifers

##### i. Unconsolidated Aquifers

No unconsolidated aquifers in the permit area are used for potable water supplies. Illinoian till is usually not considered an aquifer because of the fine grain size that produces low permeability and low yields. Water tables generally conform to topography and flow directions are primarily toward local drainages although there may be a minor component of flow downward to bedrock aquifers.

##### ii. Bedrock Aquifers

No consolidated aquifers in the permit area are used for potable water supplies. Consolidated bedrock aquifers in southern Indiana are composed primarily of sandstone of Pennsylvanian age and limestone of Mississippian age. Groundwater flows in fractures, along bedding planes, in the cleats of coal seams, and in unfractured sandstone with sufficient permeability. Shales, siltstones and underclays are generally considered confining layers. Fractures caused by jointing or faulting can reduce the confining effect of these units. Fracturing generally decreases with depth.

#### 11. Alternatives Analysis

After careful consideration, no alternatives to the planned disturbance are available without leaving a large volume of high quality coal reserve and additionally incurring very large avoidance costs. The size of the area to be disturbed has been minimized to the highest degree possible considering the presence of mine-able coal reserves. Mitigation is proposed for all regulated disturbances. The temporary impacts covered by this permit include coal mining activities for a 4-5 year period. Current plans are to mine the Bear Run Mine (Amendment 4) reserve in the 2010 - 2015 time period. The nearby Farmersburg Mine has been downsizing in conjunction with the Bear Run start up and will close in the August-September 2010 timeframe. Remaining equipment and employees are being transferred to the Bear Run Mine.

The original Bear Run Mine is a multi-seam surface mine with a high quality economically feasible coal reserve consisting of ~ 19 million recoverable tons. This amendment will add an additional ~ 42.5 million recoverable tons, and will provide ~ 274 billion kilowatt hours of electricity. Facility construction of the original Bear Run reserve has been completed and is in operation. The mine will consist of open pits, haul roads, processing plant, sediment basins, etc. The planned impacts to the Amendment 4 permit area will consist almost entirely of coal extraction activities; since processing, maintenance, transportation and management facilities are in place and are not planned to be expanded. Perimeter impacts will be necessary for sediment control diversions and basins; however, disturbance for these required activities will be minimized by locating them as close to the coal extraction area as possible. Necessary haul roads for the Amendment 4 area will be constructed across previously mined areas and follow the coal extraction pits, thereby avoiding additional impacts outside of the mining area. The Bear Run Mine will provide a source of high quality coal for long term coal supply agreements with regional electric utility companies.

Peabody Midwest Mining, LLC has very significant resources invested in the acquisition of land, coal reserves, mining equipment, etc. Construction of a processing plant, shop, and rail loading facility has been completed and was located on previously mined land. The fact the area has already been mined will allow avoidance and minimization of disturbance to additional unmined areas. The mining operation will expand in production as the Farmersburg Mine in Vigo and Sullivan counties declines in production and ultimately closes. This additional mining area will facilitate an overall annual production increase to approximately 8 million tons by 2011-12. This will provide an uninterrupted supply of coal to the regional utilities, as well as, steady continuous employment to over 370 local [and area residents \(including some from recently closed mines such as the Farmersburg Mine\)](#) by the end of 2010. As production reaches its maximum, the direct employment level will exceed 460 at the mine with annual wages and benefits totaling \$58 million. Additionally, the mine operation is estimated to generate \$3.8 million in annual tax revenue to Sullivan County and the state of Indiana. Many private landowners have received and will continue to receive significant income from the mining operation in the form of royalty payments and/or acquisition proceeds. Please see Appendix L additional direct and indirect economic impact estimates. The economic impact model was completed using the U.S. Dept of Commerce's RIMS II techniques.

There essentially are no practical or economical alternatives to the proposed surface mining method of coal extraction. The coal reserve exists in four separate seams, with a unique distribution pattern and thickness. Alternative methods of mining including conventional underground, longwall mining, auger and highwall mining and pod mining have been reviewed, but are not feasible for the Bear Run project. Further explanation is provided below. Not mining the Bear Run Mine (Amendment 4) reserve would result in the loss of high paying jobs, important tax revenue, huge financial losses on investment to Peabody Midwest Mining, LLC [and a significant interruption to the coal supply necessary for basic electricity production in the state of Indiana and the United States.](#) [Electricity-generating customer companies depend on specific coal qualities and committed tonnages to maintain adequate feedstock for reliable uninterrupted power generation for their millions of customers.](#) The Summary of Alternatives table identifies the alternatives considered and their primary attributes. The table is followed by the comprehensive Alternatives Analysis narrative.

Four (4) alternatives were considered for the Bear Run Mine (Amendment 4) mining operation.

- A. "No Action" Alternative (No surface mining)
- B. "Preferred Action" Alternative (Conduct surface mining in the proposed location)
- C. "Project Relocation" Alternative (Relocate to another site)
- D. "Other Mining Techniques" Alternative (Conventional room and pillar, longwall, auger and highwall mining, pod mining)

Summary of Alternatives

Alternative	Description	Advantages	Disadvantages	Result of Implementing Alternative
<u>No Action Alternative</u>	No Surface Mining at Bear Run Mine (Amendment 4) mine site	<ul style="list-style-type: none"> <li>Eliminates mining related disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Without regulated mining activities, deforestation can occur without effective NPDES controls, without replanting and monitoring requirements and without proper Indiana Bat protection measures.</li> <li>Expansion of agricultural fields are likely to occur.</li> <li>Loss of ~460 direct jobs with annual wages and benefits of ~\$58 million</li> <li>Loss of ~\$3.8 million in annual tax revenue for Sullivan County and State of Indiana</li> <li>Loss on investments in the acquisition of the equipment, facilities, land, coal reserve and permitting that have been made in advance of mining.</li> <li>Further degradation of existing jurisdictional waters from agriculture and downstream straightening.</li> <li>Off site mitigation will not be completed.</li> <li>No protection of restored streams/wetlands through proposed deed restrictions.</li> <li>Threatens necessary coal supply for regional electric utilities.</li> </ul>	<ul style="list-style-type: none"> <li>Fails to meet Peabody Midwest Mining, LLC's purpose and need of utilizing this viable energy reserve</li> <li>Loss of high quality coal reserve for regional electric utilities</li> <li>Does not meet project objective</li> </ul>
<u>Preferred Action Alternative</u>	Surface Mining at Bear Run Mine (Amendment 4) mine site	<ul style="list-style-type: none"> <li>Allows Peabody Midwest Mining, LLC's to fully utilize this viable resource and supply to Regional utilities resulting in affordable electricity for the regional community.</li> <li>Maximizes coal recovery of the reserve and minimizes impacts at other sites.</li> <li>Provides ~460 direct jobs with a payroll of ~\$58 million annually</li> <li>Provides tax revenue to Sullivan County and the State of Indiana</li> <li>Impacts to existing streams and wetlands will be mitigated on-site, with additional off-site mitigation.</li> </ul>	<ul style="list-style-type: none"> <li>Staged, temporal loss of the functions of disturbed streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Meets Peabody Midwest Mining, LLC's purpose and need of utilizing this viable energy reserve</li> <li>Provides high quality coal reserve for regional electric utilities</li> </ul>

		<ul style="list-style-type: none"> <li>• Disturbance minimized to maximum extent</li> <li>• Reclamation of the site will be closely monitored by multiple state and federal agencies.</li> <li>• Protection of streams/wetlands through proposed deed restrictions</li> </ul>		
<u>Project Relocation Alternative</u>	Surface Mining at another location	<ul style="list-style-type: none"> <li>• Eliminates disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>• A comparable reserve in the Illinois basin does not likely exist, resulting in multiple sites being needed to replace the planned Bear Run production.</li> <li>• Does not utilize Bear Run (Amendment 4) viable reserve or existing facilities</li> <li>• Does not assure the site will not be significantly disturbed by activity now or in the future without the regulated requirements contained in SMCRA and CWA Section 404 permits.</li> <li>• Produces similar or greater impacts to another site with more disturbance likely needed to produce the same amount of coal.</li> <li>• Threatens needed coal supply to regional electric utilities while replacement supplies are located, acquired and permitted.</li> </ul>	<ul style="list-style-type: none"> <li>• Fails to meet Peabody Midwest Mining, LLC's purpose and need of utilizing this viable energy reserve</li> <li>• Loss of high quality coal reserve for regional electric utilities</li> <li>• Does not meet project objective</li> </ul>

<u>Other Mining Techniques Alternative</u>	Conventional Room and Pillar or Longwall Mining	<ul style="list-style-type: none"> <li>Reduce surface disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Geologic conditions are not conducive to longwall mining (individual coal seam too thin and thickness and composition of overburden)</li> <li>Does not fully utilize Bear Run's viable reserve as recovery would be less than 50% (conventional) to 80% (long wall) of the seam longwall mined</li> <li>Surface subsidence is immediate, which may considerably affect streams and wetlands</li> <li>Does not assure the site will not be significantly disturbed by activity now or in the future</li> <li>Does not eliminate surface disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Operational cost and safety issues render this alternative impractical, as well as failing to fully utilize this viable energy reserve</li> <li>Does not meet project objective</li> </ul>
	Augering	<ul style="list-style-type: none"> <li>Reduce disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Excavation and backfilling of numerous pits to maximize auger coal recovery</li> <li>Does not fully utilize Bear Run's viable reserve as recovery would be less than 50% on the seam augered</li> <li>Does not assure the site will not be significantly disturbed by activity now or in the future</li> <li>Does not eliminate surface disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> <li>Not a viable method for continuous, consistent coal production</li> </ul>	<ul style="list-style-type: none"> <li>Operational costs render this alternative impractical, as well as failing to fully utilize this viable energy reserve</li> <li>Does not meet project objective</li> </ul>
	Pod Mining	<ul style="list-style-type: none"> <li>Reduce disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Excavation and backfilling of numerous pits to maximize pod recovery</li> <li>Does not fully utilize Bear Run's viable coal reserve and existing facilities</li> <li>Recovery of reserves would be less than 50% on the coal seams pod mined</li> <li>Does not assure the site will not be significantly disturbed by activity now or in the future</li> <li>Does not eliminate surface disturbance of streams and wetlands at the Bear Run Mine (Amendment 4) mine site</li> </ul>	<ul style="list-style-type: none"> <li>Operational costs render this alternative impractical, as well as failing to fully utilize this viable energy reserve</li> <li>Does not meet project objective</li> </ul>

A detailed description of each of the alternatives follows:

- A. The *"No Action"* Alternative is to not continue or expand the existing mining operation, as well as other similar mining operations in the Midwest. The existing open pits and mine infrastructure would have to be reproduced in other similar sites to replace the lost coal reserve. [The four coal seams to be mined by this operation on average generate 20,000 tons per acre. Most surface coal mines in the Midwest mine from one seam to three seams of coal. The Bear Run reserve represents one of the largest recoverable tons per acres of mineable coal in the Illinois Basin. For comparison, the Farmersburg Mine has been the largest-producing surface mine in the Illinois Basin for the past decade and averaged coal recovery of 7,800 tons per acre. To mine the same amount of coal, one acre of disturbance at Bear Run Mine would have required 2.6 acres at the Farmersburg Mine to meet the same tonnage. For the approximately 8,500 acres mined at Farmersburg; an additional 13,600 more acres would have been required.](#) The *"No Action"* alternative would result in many negative side effects:
- Loss of ~ 460 current and future direct jobs with a payroll of ~ \$58 million annually when full production is reached. Many of the employees are long term employees in the mining industry and are not currently trained for other employment. The mining industry is vitally important to the local economy of Sullivan County, as well as to the region and state. Unemployment rates as of June 2010 were estimated at 9.8% for Sullivan County, 10% for Indiana and 9.7% for the United States<sup>47</sup>.
  - Over half of the electricity produced in the U.S. and over 95% of the electricity produced in Indiana comes from coal-fired power plants. The economical availability of high quality coal is paramount to the local, state and national economy and national security. Elimination of ~25% of the annual coal production in Indiana ([based on the 30 million tons Indiana produces in a year](#)) would result in a very serious supply deficit for Regional utilities. This is especially true at a time when supplies are interrupted in other coal producing regions of the U.S.
  - The loss in tax revenue, both direct and indirect would be significant, particularly when the replacement industry is unknown, and most local, state and federal governments are operating under significant deficit spending.
  - The economic losses to the company would be immense as huge investments in land, coal reserves, equipment and infrastructure have been made well in advance using a business plan dependent on maximizing recovery of the reserve. The majority of these things cannot be moved to other locations. Those items that can be relocated are at a significant additional cost and time, and will likely result in greater impacts at new unknown sites.
- B. The *"Preferred Action"* alternative is to follow the proposed surface mining plan. This will maximize coal recovery and ensure re-disturbance does not occur in the future when coal and overall energy demand is projected to increase. Steps will be taken, as always, to minimize effects to the aquatic resources by placing required sediment basins and diversions as close to the coal extraction area as possible.

The permit boundary has been restricted to the maximum extent possible to allow efficient and effective mining of the reserve. The eastern edge of the permit boundary abuts the previously approved Section 404 permit area for the Bear Run Mine (East Pit) where surface coal mining and coal preparation facilities will be located. Mining will be initiated in the Bear Run Mine (East Pit) and advance into the Bear Run (Amendment 4) area. The southern, northern, and western boundaries of the permit area are determined by the proposed mining plan. Previously mined and reclaimed area in Area 3 was included in the permit for boxcut spoil placement, drainage control and mine support. It is desirable to place the boxcut spoil in this area as it provides for suitable placement of the initial overburden for mining area in Area 3 due to the existing large open water impoundments and straightened streams and unplanned wetlands that have developed. The boxcut spoil area has already been mined. Soil stockpiles will also be placed in adjacent upland areas outside of the streams and wetlands. Large acreages of unmined land have been avoided through utilization of previously mined areas for the preparation plant, shop and offices, haul roads, plant make-up water, refuse disposal, box cut spoil placement and sediment control measures. Advance disturbance will be minimized and concurrent high quality reclamation will be ongoing to keep the disturbed area to a minimum at any given time. Best Management Practices will be utilized to guard against negative impacts to the aquatic ecosystem outside of the area planned for mining. Best Management Practices include retention and

monitoring of site run-off, use of quick growing cover crops, and silt fencing. In addition, temporary and permanent terracing and erosion control systems and filter strips will be employed in reclaimed agricultural fields. Stream and wetland mitigation will take place as quickly as practicable, employing the best techniques available to ensure successful mitigation. Mitigation areas will be monitored closely by well-trained staff and outside consultants will be utilized as needed (staff and consultant credentials provided in Section 5.D.)

The Bear Run (Amendment 4) project area has been selected for a number of factors making the site unique:

- Coal quantity is the most important component of the site selection. The four coal seams to be mined by this operation on average generate 20,000 tons per acre. Most surface coal mine sites in the Midwest mine from one seam to three seams of coal. The Bear Run reserve represents one of the largest recoverable tons per acres of mineable coal in the Illinois Basin. For comparison, the Farmersburg Mine has been the largest-producing surface mine in the Illinois Basin for the past decade and averaged coal recovery of 7,800 tons per acre. [To mine the same amount of coal, one acre of disturbance at Bear Run Mine would have required 2.6 acres at the Farmersburg Mine to meet the same tonnage. For the approximately 8,500 acres mined at Farmersburg; an additional 13,600 more acres would have been required. This could have potentially disturbed approximately 900,000 feet of streams and approximately 80 acres of wetlands utilizing the wetland and stream densities discussed in the Cumulative Analysis section for the Bear Run \(Amendment 4\) permit area.](#) Surface mining is the only available method to safely and efficiently extract the [extensive available coal reserve](#) and eliminate future impacts. The unique features of the Bear Run coal reserve are discussed further in part D of the Alternatives Analysis.
  - Property and mineral control - surface property and coal reserves were acquired at a substantial cost. It is not economically feasible to relocate this site to an uncontrolled area even if an acceptable reserve was available. The lost time and additional investment with an unknown conclusion eliminate this as an option from a practical business perspective. Property control/access must be acquired before aquatic resources can be evaluated.
  - Existing land use and site location - land uses are primarily cropland, forest and previously mined areas. Topography is flat to rolling. The site occurs in a rural sparsely populated setting and is isolated from most nearby residences. Existing land uses on previously mined areas at the site have a long history of successful reclamation and reestablishment as post-mining land uses. Previously affected areas are being utilized to the extent possible for mining support facilities in order to avoid and minimize additional impacts to unmined lands.
  - Coal quality - the coal seams to be mined by this operation are the Indiana No. 7, No. 6, No. 5A, and No. 5. These are needed, compatible fuel sources for existing coal-fired power plants which must continue to operate and produce electricity that is crucial to the economy and security of the United States. The average Btu content of the final saleable coal is ~11,000. While alternate sources of power generation are being developed on varying scale throughout the country, there is no viable, scaleable or economic replacement for coal in the foreseeable future.
  - Marketability - the site location allows for efficient access to existing infrastructure that currently supports transportation of coal to customers for energy production. Indiana Rail Road has recently completed a rail spur into the Bear Run site that provides access to rail lines which are located strategically to coal-fired electric utilities. Rail delivery will be the primary method of delivery of coal to the mine's customers, thereby reducing potential traffic onto local public roads.
- C. The "*Project Relocation*" Alternative is not a viable alternative as essentially the same or more aquatic resources would be encountered at any mining location in the Midwest. Another location would, in fact, require additional disturbance of natural areas for infrastructure construction. In addition, the potential mining locations are dictated by the site specific geology. Unlike many other industries, coal mining cannot be relocated to more desirable areas if they exist. The mine must be located where the mineable reserve is located. Relocation would likely result in significant increased impacts at multiple sites to equal the planned production and available tons per acre of Bear Run. Economically mineable

surface coal reserves are declining in the Illinois Basin and will continue to do so in the future. The Bear run reserve is one of the last large surface mineable deposits left in the region. The Bear Run site was chosen because of the factors mentioned above.

- D. The use of "*Other Mining Techniques*" to recover the coal reserve is considered during the planning and permitting processes. In most cases, a coal reserve is essentially either suitable for surface mining or underground mining. *Underground mining*, either by longwall or room and pillar, auger and highwall mining and pod mining scenarios have been evaluated and rejected as alternatives to surface mining. Explanations are provided below.

Past experience at Peabody's Illinois Basin room and pillar operations have resulted in conclusions that a minimum average coal thickness of 5 feet is needed before an underground operation is even considered for evaluation in the No. 5 or No. 6 coal seam due to economic factors, safety and an available workforce. Furthermore, in existing *underground mines* owned or operated by Peabody, mining extents do not extend into areas where the No. 5 or No. 6 coal seam thickness is less than 4.5 feet. None of the existing coal seams meet either of these minimum requirements. The thickest seams are the No. 5 seam which is ~3.9 feet thick and the No. 6 seam which is 3.7 feet thick in the Amendment 4 area. The average depth to No. 6 seam is ~ 140 feet while the average depth to the No. 5 seam is 220 feet; however, the No. 5A seam is on average only ~21 feet above the No. 5 seam. The close proximity of the coal seams likely would cause weakened roof conditions, increased safety concerns, and further eliminate underground mining as an option. Based on seam thicknesses, if underground mining was feasible in the No. 5 or No. 6 seam, approximately 85% of the coal reserve would be left in place. If both the No. 5 and No. 6 seam could be mined from underground, 79% of the coal reserve would be left in place. This enormous reduction in reserve would not support the existing and future investment in the mining infrastructure. Furthermore, it would take several separate mines with associated infrastructure to replace the annual production planned at Bear Run. Thinner seams are mineable in the Appalachian coal region due to higher Btu and lower sulfur content and much different geological conditions.

*Longwall mining* has not been attempted in Indiana to date, but the same conditions described above would prohibit longwall mining as an option. In addition, longwall mining results in land subsidence which would have an unknown impact to the existing aquatic resources.

*Auger Mining* is only a supplement to surface mining in limited circumstances. There is less opportunity for auger mining in conditions similar to Bear Run where multiple seams will be mined to 220 foot depth. The order and organization of in-pit operations is critical to the efficient and safe operation of the mine. Auger mining requires pit areas to be idled from the normal stripping operation while augering occurs. This delays and increases the costs of reclamation by forcing rehandling of material to fill the voids that are left open for augering. In addition, the pit depth at Bear Run would require additional highwall laybacks to ensure safe working conditions for any auger mining crew below. Recovery is less than 50% on any coal seam, and auger penetration is limited to 300 feet in best cases. Rolling coal seams similar to those at Bear Run further limit recovery by augering operations. Peabody Midwest Mining, LLC includes augering options in its' SMCRA permits to provide options for maximizing coal recovery at pit ends and final pits, but historically augering activities have proven to not be cost effective in most circumstances. Use of a *highwall miner* allows deeper (800-900 feet) extraction than a conventional auger and slightly higher recovery (~55%), but it also creates even more complications from an operational and consistent productions standpoint. Even larger working areas are required to accommodate use of a highwall miner and further increases reclamation costs and prevents consistent production to meet utility needs.

*Pod mining* would consist of the excavation of smaller pits in between the aquatic resources since the coal reserve at the Bear Run Mine consists of four (4) separate seams; the Indiana No. 7, No. 6, No. 5A, and No. 5 seams down to a depth of approximately 220 feet. This technique would make mining economically unfeasible as mining costs would increase significantly while coal recovery would diminish dramatically. Furthermore, it would not be possible to physically extract all four seams in the smaller shorter pits. The lower two seams of coal would likely have to be left, but the mining ratio is too high to allow extraction of the upper seams. Additional lay backs would be needed to allow for construction of separate diversions and sediment basins for each pod area. The overburden from each pit would have to be stockpiled and then re-deposited into the pit after coal removal, as opposed to conventional surface mining where pits advance continuously with overburden being deposited into the previous pit.

Coal recovery would be lost under each aquatic resource, the related pit and drainage control lay back areas and overburden stockpile area. Use of auger mining or highwall mining would increase coal recovery slightly, but further increase the operating costs and disjointed production.

Besides the uncommonly high coal tons per acre at Bear Run, another unique aspect is the depth and distribution of the coal seams and the resulting mining ratio. Based on historical data and the current coal market, Peabody's Midwest Operations use an average 20:1 mining ratio as its' basis for whether a reserve can be economically mined from a surface operation standpoint. The ratios of the Bear Run Mine (Amendment 4) reserve calculated from the surface to each seam is as follows: The No. 7 seam ratio is 40:1, the No. 6 seam ratio is 27:1, the No. 5A seam ratio is 25:1 and the No. 5 seam ratio is 19:1. This information is presented to illustrate that all 4 seams must be mined in order to be economically feasible. This fact coupled with the depth to the lowest seam cause avoidance of aquatic resources to be unfeasible. The only manner in which this mine can operate efficiently and safely is to open a pit once and advance consistently to the end of the mining. A cost analysis of avoiding intermittent streams and wetlands in close proximity is outlined below and illustrated on Map E in Appendix A.

Avoiding the intermittent streams and larger wetlands in close proximity to the intermittent streams creates many costly operating difficulties and inefficiencies. *Pod mining* forces additional box cut excavations, additional final pit reclamation, interruptions in direct haulback reclamation, additional sediment basin and diversion construction, additional haul road construction and reclamation, decreased and inconsistent coal production, inconsistent equipment and workforce needs, as well as significantly reducing the coal reserve. The spoil generated from the additional box cut excavations will have to be hauled to the previous final pit for deposition once mining is completed in the previous pit. Sediment basins and diversion ditches will have to be constructed for active and post-mining drainage control requirements. Haul roads that otherwise would not be needed will have to be constructed to facilitate the additional box cut excavations.

Diversions	= 33,000 LF, 3' depth, 4' wide bottom w/ 3:1 side slopes = 47,600 cy X \$1.25/cy	= \$ 59,500
Sed Basins	= 8 basins, average 15 ac-ft each = 193,600 cy X \$1.50/cy	= \$ 290,400
Add. Box Cut 1	= 3,700 LF, 150' wide pit, 2.5 pits hauled, 205' depth Average haul distance 5,900 LF to final pits 1 & 3 = 10,534,700 cy X \$1.56 cy	= \$16,434,000
Add. Box Cut 2	= 1,200 LF, 150' wide pit, 2.5 pits hauled, 205' depth Average haul distance 3,100 LF to final pit 2 = 3,416,600 cy X \$1.19/cy	= \$ 4,065,000
Add. Box Cut 3	= 2,400 LF, 150' wide pit, 2.5 pits hauled, 205' depth Average haul distance 5,500 LF to final pit 4 = 6,833,300 cy X \$1.51/cy.	= \$10,318,000
Add. Box Cut 4	= 2,400 LF, 150' wide pit, 2.5 pits hauled, 205' depth Average haul distance 2,700 LF to final pit 4 = 6,833,300 cy X \$1.19/cy	= \$ 8,131,000
Resoil Final Pits	= Extra cost of stockpiling soil vs. normal direct placement (4' depth) = 248 acres (Final Pits 1,2,3,4 & 5) (9,000' L X 1,200' W) = 1,600,426 cy X \$1.25/cy	= \$ 2,000,533

Reclamation of Additional Haul roads: (Assume construction is part of mining/box cut efforts and soil will be stockpiles adjacent to road) (Final grading at 1.5' depth, 4' depth of soil)  
= Haul road width of 100', associated shoulders, ditches of 40'  
= 17,200 LF X 140' width = 55.3 acres

Grading	= 55.3 acres X 1.5' depth X \$.70/cy	= \$ 93,000
Soil Replaced	= 55.3 acres X 4' depth X \$.70/cy	= \$ 249,000

Loss of Coal from intermittent streams, adjacent wetlands and additional isolated areas is estimated to 520 acres with ~20,000 tons/acre = 10.4 million tons or 67 billion kilowatt hours of electricity.  
Lost Revenue estimate = \$400,000,000

The primary additional costs outlined above that would be incurred by the Bear Run operation if it were required to avoid intermittent streams total \$39,839,900. In addition, over 10 million tons of coal would be left in place and the lost revenue would equate to at least \$400 million. These costs and lost revenue result prevent pod mining from being a viable option. The Amendment 4 area cannot be mined under this scenario for economic reasons. This example is presented to illustrate the extra costs, but it is also very likely coal recovery would be even less considering the depth and practical extraction capabilities in the avoidance distances given. Also, the current planned pit configuration to produce 8 million tons/year requires working pit lengths of at least 7,000 feet. The pod mining scenario only allows this minimum pit length in a few locations.

Also, not considered is the fragmented landscape that will result from the avoidance. The opportunity to reconstruct streams, wetlands and floodplains as complimentary components of a stable high value aquatic drainage system will not be available. Wetland mitigation will be minimal, and large blocks of hardwood forested wetlands will not be undertaken. In addition, the offered off-site wetland and stream mitigation would not be needed. Local public roads will also be fragmented as smaller portions will be mined through and decrease opportunities to improve public roads from a safety standpoint.

The proposed mining plan not only maximizes resource recovery but is also necessary if the area is to be mined at all. Although mining alternatives such as pod mining have been evaluated, they have been eliminated as viable options because of added cost, loss of revenue and operating limitations. As stated previously, there are no legitimate alternatives to the surface mining method of coal removal for the reserve. The only alternative would be to cease mining, resulting in the loss of high paying jobs, important tax revenue, ancillary economic growth, huge financial losses on investment to Peabody Midwest Mining, LLC and an interruption to the coal supply necessary for basic electricity production in Indiana and the nation. It should be noted that, mining returns the land to a natural state as opposed to other land uses such as commercial developments, housing developments, etc. which essentially alter the land use long term or permanently.

## 12. Social and Economic Importance

Mining is different from many other industries in that the mine and support facilities must be located where the resources occur. Other factors such as proximity to transportation, transmission lines, and reserve configuration dictate facility locations and are critically important to the viability and success of an operation. Reserves may be owned or controlled many years before mining occurs and involve a substantial long-term investment.

Coal mining is regarded to be of social and economic importance by Indiana Statute. *IC14-34-1-3 (7) Assure that the coal supply essential to the nation's energy requirements and economic and social well-being is provided and strike a balance between protection of the environment and agricultural productivity and the nation's need for coal as an essential source of energy.*

Further, an additional Indiana Statute requires that operations be conducted in a manner that maximizes the use of the coal resource. *IC 14-34-10-2 Duties of permittee ... (b) In addition to other standards a permittee must meet under rules of the commission, a permittee shall do the following: ... (2) Conduct the surface coal mining operation in a manner that maximizes the use and conservation of the solid fuel resource that is recovered so that re-affecting the land in the future through surface coal mining is minimized.*

Coal is Indiana's major energy source with 95 percent of its electricity generated from coal. Indiana coal mining provides not only many high paying jobs directly, but many ancillary jobs as well. A typical coal mine will contribute approximately 100 million dollars per year to the state economy. The cost of electricity is a major cost for industry and can affect the decision to locate new industries in Indiana. Approximately 50 percent of Indiana's electricity is consumed by industry. Even more fundamental, keeping the cost of electricity low helps to provide affordable energy to Indiana's citizens, especially those on fixed incomes. The social benefit of low cost energy is immeasurable.

Further, coal is a vital national resource and is crucial to the security of the nation. Coal constitutes 85 percent of America's fossil energy reserve and its consumption in the United States and the world is increasing.

13. Cumulative Activity: To assess cumulative impacts to the environment, the analysis should include the effect of the proposed activity, along with other activities that have occurred in the past, are occurring in the present, or will occur in the reasonable foreseeable future.

In assessing the cumulative impacts, both Bear Run permits (the pending Bear Run (Amendment 4) and the approved Bear Run (East Pit) will be combined and referred to as the Bear Run Project in the following sections. [Cumulative surface effects for the Bear Run Reserve \(Bear Run Project and any future amendments\) begins on page 30 of this permit narrative.](#) The sections that follow the watershed analysis describe the factors that may be impacted by the development of Bear Run Project. Two levels of cumulative impacts will be considered, where applicable: local impacts within the 14-digit HUC watersheds and the regional impacts within the 8-digit HUC watersheds.

An evaluation of the following information demonstrates that activity associated with the Bear Run Project has minimal impacts compared to the overall impacts to the cumulative watersheds.

The activities authorized for the Bear Run Project will occur within two 8-digit watersheds: the Middle Wabash - Busseron (05120111) and the Lower White (05120202). The Middle Wabash-Busseron drains west-central Indiana via Busseron Creek to the Wabash River. The Middle Wabash-Busseron watershed begins about 15 miles north of Terre Haute, near the Vermillion-Parke-Vigo County line. From there, the Wabash River flows to the southwest, forming the boundary between Indiana and Illinois just southwest of Terre Haute. Busseron Creek is located primarily in Sullivan County and flows to the southwest for about 30 miles before discharging into the Wabash River west of Carlisle. The Middle-Wabash-Busseron ends just south of Vincennes, where it becomes the Lower Wabash watershed. The main tributaries to Busseron Creek that will be impacted by the Bear Run Project will be Buttermilk Creek, Middle Fork Creek, and Maria Creek.

The Lower White watershed is the lower portion of the White River watershed (also known as the West Fork White River) located in west central Indiana. The Lower White watershed begins near Gosport, Indiana and flows southwest to its confluence with the Wabash River near the town of East Mount Carmel, in Gibson County. The watershed covers portions of Brown, Daviess, Gibson, Greene, Knox, Martin, Monroe, Owen, Pike, and Sullivan counties. The Lower White watershed receives flow from the Upper Whiter River, the East Fork White River, and the Eel River drainage basins. The main tributaries to the West Fork White River that will be impacted by the Bear Run Project are Pollard Ditch, Singer Ditch, and Black Creek.

The Bear Run Project will impact portions of seven 14-digit HUC watersheds: Buttermilk Creek, Middle Fork Creek (Sullivan), Maria Creek-Headwaters, White River-Pollard Ditch, Singer Ditch (upper)-Hill Ditch, Black Creek-Brewer Ditch, and Black Creek (Ditch)-Headwaters.

The following tables show the percentages of watershed that will be affected by the Bear Run Project.

14-Digit HUC Watershed Cumulative Impact Summary							
Watershed <sup>1</sup>	Watershed Area <sup>1</sup>	Bear Run (East Pit)	Percent of Watershed	Bear Run (Amendment 4)	Percent of Watershed	Bear Run Project	Percent of Watershed
	(acre)	(acre)	(percent)	(acre)	(percent)	(acre)	(percent)
Buttermilk Creek	13,364	12.3	0.1	77.8	0.6	90.1	0.7
Middle Fork Creek (Sullivan)	15,821	1,322.3	8.4	49.9	0.3	1,372.2	8.7
Maria Creek - Headwaters	17,505	0	0	342.0	2.0	342.0	2.0
White River - Pollard Ditch	17,493	237.6	1.4	1,714.5	9.8	1,952.1	11.2
Singer Ditch (upper)-Hill Ditch	12,147	19.7	0.2	0	0	19.7	0.2
Black Creek - Brewer Ditch	12,799	2,016.9	15.8	482.3	0.6	2,499.2	19.5
Black Creek Headwaters	22,083	2,083.6	9.4	0	0	2,083.6	9.4

8-Digit HUC Watershed Cumulative Impact Summary							
Watershed <sup>1</sup>	Watershed Area <sup>1</sup>	Bear Run (East Pit)	Percent of Watershed	Bear Run (Amendment 4)	Percent of Watershed	Bear Run Project	Percent of Watershed
	(acre)	(acre)	(percent)	(acre)	(percent)	(acre)	(percent)
Middle Wabash - Busseron (Indiana)	718,412	1,334.2	0.2	469.7	0.1	1,803.9	0.3
Lower White	1,070,965	3,141.8	0.3	2,196.8	0.2	5,338.6	0.5

In terms of percentages of watershed, Black Creek-Brewer Ditch potentially could be impacted the most by the Bear Run Project with approximately 19.5% of the watershed affected. The majority of the impacts will occur under the approved Bear Run (East Pit) permit (15.8%), but it should be noted that a large portion of this area has been previously surface mined and reclaimed as the Hawthorn Mine. The state-of-the-art coal preparation plant and rail loadout facilities for the Bear Run Project will be located in this local watershed which will be affected by these facilities for the life of the Bear Run Mine with coal stockpiles, haul trucks, and rail traffic. The other watersheds will be affected primarily by surface mining and reclamation during and after mining operations have ceased. The reclaimed lands will be returned to land uses commensurate with the pre-mine conditions. Reclaimed land will include agriculture, forests, pastures, wildlife habitat and open water.

#### Land Resources

The Bear Run Project is located in the Glaciated Wabash Lowlands ecoregion which is characterized by land that is often mantled by till or windblown silt and sand that are pre-Wisconsinan in age. This broad, undulating lowland was formed in non-resistant, non-calcareous sedimentary rock which was glaciated. Many wide, flat-bottomed, terraced valleys occur and are filled with alluvium as well as outwash, aeolian, and lacustrine deposits. Patterns of land use vary within the ecoregion. Drained alluvial soils are farmed while un-drained valleys are used for pasture or remain wooded. Upland soils are used for farming and livestock. The original vegetation included beech and oak-hickory forests with isolated prairies. Today, the productive soils support corn, soybean, wheat, and vegetable farming with scattered wooded areas. Coal mining has also occurred in this ecoregion as it is located along the rim of the Illinois Basin where coal deposits outcrop or occur at recoverable depths.

The following tables summarize the various land covers within the local 14-digit HUC watersheds covered by the Bear Run Project and the adjacent regional 8-digit HUC watersheds along with the acreage that has been previously affected by mining.

14-Digit HUC Watershed Land Cover Summary								
Watershed <sup>1</sup>	Watershed Area <sup>1</sup>	Previously Affected by Mining	Agriculture including Pasture	Forest / Wildlife	Developed	Water/ Wetlands	Undeveloped	Source of Information
	(acre)	(acre)	(percent)	(percent)	(percent)	(percent)	(percent)	
Buttermilk Creek	13,364	6,323	27	60	4	8	1	Aerial Photo
Middle Fork Creek (Sullivan)	15,821	333	70	25	1	1	3	Aerial Photo
Maria Creek Headwaters	17,505	375	78	20	1	1	0	Aerial Photo
White River - Pollard Ditch	17,493	3,519	76	19	2	2	1	Aerial Photo
Singer Ditch (upper)-Hill Ditch	12,147	4,266	70	20	2	5	3	Aerial Photo
Black Creek - Brewer Ditch	12,799	5,336	35	58	1	5	1	Aerial Photo
Black Creek (Ditch)-Headwaters	22,083	5,541	40	51	0	7	2	Aerial Photo

8-Digit HUC Watershed Land Cover Summary								
Watershed <sup>1</sup>	Watershed Area <sup>1</sup>	Previously Affected by Mining	Agriculture including Pasture	Forest / Wildlife	Developed	Water/ Wetlands	Undeveloped	Source of Information
	(acre)	(acre)	(percent)	(percent)	(percent)	(percent)	(percent)	
Middle Wabash - Busseron (Indiana)	718,412	57,536	70	19	4	7		15
Lower White	1,070,965	49,534	49	41	8	2		16

As shown by the above tables, agriculture is a significant land use in the Middle Wabash-Busseron watershed. The Lower White has a lower percentage of agriculture due to the watershed being dissected by two distinctly different ecoregions. The western half of the Lower White is primarily located in the Glaciated Wabash Lowlands ecoregion which is discussed above. The eastern half of the watershed is located across three minor ecoregions of the Interior Plateau: the Crawford Uplands, the Mitchell Plain, and the Norman Uplands. The Interior Plateau has rolling to deeply dissected, rugged terrain with areas of karst topography on the Mitchell Plain which does not support the scale of farming as in the Lowlands. The land cover is a mix of agriculture (both livestock and grain) and forest.

In the Glaciated Wabash Lowlands, crop and livestock production have impacted stream water quality and stream habitat due to erosion off the cultivated fields. A number of farmers incorporate soil conservation practices to retain topsoil, but the majority fails to do so. The following table shows the cropping conditions that were practiced in 2004 for Sullivan County, which has an area of 290,560 acres.

2004 Sullivan County Cropping Practices <sup>17,18</sup>		
Practice	Soybeans	Corn
	(acre)	(acre)
No Till	21,450	7,800
Mulch Till	18,200	2,600
Reduce Till	5,525	1,300
Conventional	13,975	52,324

As shown by the above table, the conventional farming practice is the predominate method used for corn and small grains production. This practice has impacted water quality ever since modern-day farming began utilizing larger tracts of land and modern machinery. Agricultural ditches were dug along field borders to facilitate farming while field tiles were installed to speed drainage of the fields. Runoff from exposed fields rapidly deposits sediment and soil amendments into adjacent streams affecting the overall water quality of the local watersheds and the region.

Baseline water quality in the local watersheds and region would greatly improve if more farmers would participate in conservation tillage practices. Conservation practices would reduce the amount of sediment introduced into the streams, decrease the amount of airborne dust, slow down runoff, and decrease the need for abundant field conditioners required for crop production. Recent trends point to an increase in conservation farming practices and a decrease in conventional tillage practices.

Coal mining associated with the Bear Run Project is a temporary use of the land. A reclamation plan which outlines the types and location of the post-mining land uses is required as a part of the SMCRA permit. The Indiana SMCRA program requires that no prime farmland be lost and that minimal forest loss occur. As such, impacts to these land uses will only be temporary. Reclamation activities will be conducted simultaneously with the mining operations to minimize the area of disturbance. All disturbed areas will drain to a sedimentation basin to ensure the appropriate quality of drainage from the Bear Run Project area.

### Coal Resources

Along with agriculture, coal mining is another large part of the economy in southwest Indiana, although the aerial impacts are comparably minor. Statistics for Sullivan County show that 177,368 acres<sup>27</sup> (61.0%) of the

county is occupied by farms and used for crops or permanent pasture compared to the 28,690 acres (9.9%) that have been previously affected by mining.

Sullivan County has a rich heritage of coal mining. The earliest account of mining was mentioned by David Thomas during his travels along the Wabash River in 1816. Though there is evidence that coal mining was present in the county in the first half of the 19<sup>th</sup> century, coal mining as an industry began with the construction of the first railroads through the region. The first railroad was put into operation in 1854. The Indiana state geologist's report for 1898 provides some interesting statistics. Of the approximately 440 square miles of Sullivan County, it is estimated that all of it is underlain by coal and of this approximately 365 square miles (233,600 acres) is underlain by a recoverable reserve. The estimated total tons in these deposits was placed at 4.6 billion tons and at the time of the report the estimated amount of recoverable coal still unmined was 950 million tons<sup>25</sup>.

Due to the geographic location in the Illinois Basin, both underground and surface mining have affected land in the receiving watersheds. The following table shows the approximate surface effects in acres for the respective watersheds. **Areas Previously Affected by Mining are those that have been either reclaimed or abandoned by any company.** Areas Currently Affected by Mining include the actively working open pit, locations of coal preparation and handling activity and areas that do not have topsoil yet placed over the spoil. Underground mining activities that include locations of surface support facilities and coal preparation and handling activity are also included. **Areas Currently Affected by Mining includes operations by all companies in the area, not just Peabody subsidiaries.** It should be noted that information on Potentially Affected by Mining acreages for other coal mine operators within the watersheds is not known. Only the permitted surface mine-able reserves are listed for Peabody subsidiaries.

Cumulative Surface Effects Summary							
Watershed	Watershed Area	Previously Affected by Mining	Percent of Watershed Previously Affected by Mining	Currently Affected by Mining	Percent of Watershed Currently Affected by Mining	Potentially Affected by Mining	Percent of Watershed Potentially Affected by Mining
	(acre)	(acre)		(acre)		(acre)	
Buttermilk Creek	13,364	6,323	47.31%	0	0.00%	58	0.43%
Middle Fork Creek (Sullivan)	15,821	333	2.10%	82	0.52%	50	0.32%
Maria Creek Headwaters	17,505	375	2.14%	0	0.00%	342	1.95%
White River - Pollard Ditch	17,493	3,519	20.12%	0	0.00%	1,049	6.00%
Black Creek - Brewer Ditch	12,799	5,336	41.69%	249	1.95%	331	2.59%
Total:	76,982	15,886	20.64%	331	0.43%	1,830	2.38%
Busseron Creek	151,336	27,062	17.88%	1,054	0.70%	1,064	0.70%
Maria Creek	62,197	375	0.60%	0	0.00%	342	0.55%
Middle Wabash - Busseron (Indiana)	718,412	57,536	8.01%	1,348	0.19%	2,362	0.33%
Black Creek	87,870	17,392	19.79%	249	0.28%	331	0.38%
Lower White	1,070,965	49,534	4.63%	1,118	0.10%	2,558	0.24%
White River	7,188,900	72,399	1.01%	1,283	0.02%	5,446	0.08%

The Bear Run reserve (Bear Run Project and foreseeable future mining) could exceed 200 million tons (approximately 20,000 tons per acre if coal thicknesses remain consistent). The actuality of mining this potential reserve is dependent on many variables including the ability to acquire property, future market conditions, **public policy**, and energy demand, coal quality and coal thickness, etc. Land and reserve acquisition is ongoing in the target expansion area which lies generally west of the Bear Run Project. The acquisition of land and coal contracts is a competitive business and very capital intensive. **The further in advance capital is spent, the less return on investment is realized. Therefore, mining companies have attempted to manage land purchasing to coincide with needs for permitting and mining. Peabody is currently re-evaluating its strategies to determine the need for earlier purchases to accommodate changing permitting requirements and timeframes.** In the present market, utility companies are less willing to make long term commitments as in the past. **On average, the estimated impact to jurisdictional waters will be similar to or less than the Amendment 4 area, as**

the ground flattens out and is occupied by more agriculture towards the west. The stream or wetland types should be similar to the Amendment 4 area with the majority of streams expected to be ephemeral. Where a higher percent of agricultural land is encountered, intermittent streams will likely be more prevalent, but overall stream length and quality would be expected to diminish. The majority of expansion would lie in the Middle Wabash-Busseron (Indiana) watershed with the remaining acreage located in the Lower White watershed. Based on the natural areas of the Amendment 4 area it is estimated that the expansion area would yield a factor of approximately 0.006 acre of wetland per acre and a stream factor of approximately 65 linear feet per acre. If assuming 200 million tons is eventually mined at the site during the next 20 - 30 years, and factors listed above hold true, an additional 400-500K linear feet of streams and 40-50 acres of wetlands could be impacted. These estimates are provided at the request of the Corps of Engineers; however, impacts could be much lower or higher due to the many unknowns discussed above.

Based on the computed natural area stream and wetland density of Bear Run (Amendment 4), the following table provides the estimated stream and wetland loss for the local watersheds based on the areas that have been previously affected by mining.

Estimated Stream and Wetland Impacts from Past Mining			
Watershed	Previously Affected by Mining	Estimated Stream Impacts	Estimated Wetland Impacts
	(acre)	(feet)	(acre)
Buttermilk Creek	6,323	411,000	38
Middle Fork Creek (Sullivan)	333	22,000	2
Maria Creek Headwaters	375	24,000	2
White River - Pollard Ditch	3,519	229,000	21
Singer Ditch (upper)-Hill Ditch	4,266	277,000	26
Black Creek - Brewer Ditch	5,336	347,000	32
Black Creek (Ditch)- Headwaters	5,541	360,000	33

The above acreage and footage impacts are estimated based on the approximately stream and wetland density calculated for the natural areas at Bear Run (Amendment 4) and cannot be verified. Before implementation of the Federal Surface Mining Control and Reclamation Act of 1977, little consideration was given to stream replacement. After 1977, reclamation was focused on reclaiming land to support a productive use which emphasized controlling sedimentation and erosion control through the use of terraces, swales, and WASCOB's. Past mining in Indiana appears to have decreased the overall stream length, but greatly increased wetland and open water acreages. Many of these areas like the Greene-Sullivan State Forest are now fish and wildlife areas and enjoyed by many citizens and visitors for recreation and nature activities. It has only been recently that natural stream design has been required by regulatory agencies.

A portion of the previously affected acreage in the Middle Wabash-Busseron and Lower White watersheds predates any law or regulation to reclaim the mined land to the standards of today. This lack of reclamation has resulted in discharge of sediment, acid mine drainage and other compounds into surface waters which has contributed to several of the receiving streams being listed on the 303(d) list for impairments (see 2010 Draft 303(d) list on page 35). It should be noted that Indiana coal operators pioneered strip mine reclamation in the United States when a group of early miners banded together to form the Indiana Coal Producers Association in 1918. They decided to revegetate the spoil banks they had created with the primary focus on reforestation to obtain a cash crop and for aesthetics. Most of the early plantings, starting in 1926 were primarily locust with some hardwoods. Not all coal companies adopted this reclamation practice until 1941 when the state of Indiana enacted the second strip mine legislation in the nation requiring that all companies make reclamation and reforestation efforts and requiring them to obtain permits and secure bonds to ensure compliance. The law included a provision for active coal companies to reforest an additional percent of previously stripped land than they mined each year to help in revegetating lands that had been abandoned without any attempt at reclamation or reforestation. The now defunct, Central Indiana Coal Company donated almost 1,400 acres of reforested lands in Sullivan and adjacent Greene County to the state of Indiana in 1935<sup>31</sup>. The Indiana Department of Natural Resources Division of Forestry created the Greene-Sullivan State Forest in 1936. Additional coal companies have donated or sold additional properties to the State. Several agreements have been made with

companies to trade mined land for unmined state-owned lands. As a result of the exchanges and donations, the Greene-Sullivan State Forest now covers almost 9,000 acres, of which over 50% has been surface mined and reforested or reclaimed. The State Forest is divided into two main areas. The forest unit, which straddles the Greene-Sullivan County line, has more than 120 lakes for fishing and boating. The Dugger unit, which is west of Dugger includes approximately 1,200 acres that was acquired from Peabody Coal Company in 1995.

According to the Indiana Geological Survey - Coal Mine Information System<sup>13</sup>, the previously mined area adjacent to and included in Area 3, Area 4, and Area 5 was mined by the Hawthorn Mine. The Hawthorn Mine was in operation from 1965 to 1999. The areas within the permit boundary have all been reclaimed which included grading of the spoil, covering it with stockpiled soils, and revegetating it with the appropriate vegetation for the approved post-mining land use. The thickness of the soil on top of the mined areas varies from 1 to 4 feet. Early soil placement was conducted with intense compaction and a shallow impermeable layer has resulted in perched water tables throughout the reclaimed areas which have resulted in a "pothole" type community of small wetlands scattered across the landscape. In areas where intense compaction of the spoil and soil did not occur such as in forest and wildlife areas, surface water infiltration and horizontal migration from the surface water impoundments are enhancing the groundwater recharge and increasing base flow to receiving streams. The Kindill #3 Mine was in operation from 1991 to 2004. Portions of the mine have yet to be reclaimed. Within the permit area is an unreclaimed pit that will be utilized and then reclaimed when the mining operations begin in earnest.

#### Abandoned Mine Lands (AML)

Areas north and east of the Bear Run Mine has been heavily mined prior to 1970. Visible signs of historic mining such as spoil piles and pit lakes still exist throughout the region. A large percentage of this land area was previously mined prior to the Surface Coal Mine Control and Reclamation Act of 1977 resulting in ungraded spoil ridges which are now heavily vegetated.

While the State of Indiana has historically required reclamation of coal mined lands since 1941, these laws had varying requirements until the federal SMCRA law was passed. The Abandoned Mine Lands (AML) Program with the Indiana Department of Natural Resources Division of Reclamation has been in service since 1982 and has been responsible for the restoration of many acres of hazardous and unproductive land. SMCRA provided for the collection of fees on active coal mining to fund this restoration and elimination of these hazards. In Indiana, the program is funded by tonnage fees from underground (13.5 cents per ton) and surface (31.5 cents per ton) mines. Approximately 17 million dollars has been spent on AML reclamation projects in Sullivan and Greene Counties as of 2009<sup>50</sup>.

The Office of Surface Mining ranks the AML sites into five categories based on the level of hazard the site poses. Priority 1 and 2 are the most serious AML problems which pose a threat to the health, safety, and general welfare of the public, Priority 3 are AML problems impacting the environment, Priority 4 involves public facilities, and Priority 5 includes the development of publicly-owned lands. Approximately 107 million dollars has been spent on AML projects in Indiana as of 2009. The Abandoned Mine Lands Program is actively working on plans and restoration projects in the area. Thousands of acres in southwest Indiana have been reclaimed and the area will only increase. These lands are being returned to a productive state while reducing sediment, erosion, and acid mine drainage into the receiving waters. The Bear Run Mine which at full production will produce 8 million tons of coal a year will contribute a minimum of \$2.2 million per year to the AML fund to remedy those adverse effects of past coal mining conducted prior to SMCRA.

#### Water Quality

Within the Bear Run Project area, none of the waters are on the Outstanding Rivers List for Indiana<sup>20</sup>. The following table provides information on each of the receiving streams along with all the assessments on the waters downstream to either the Wabash or White Rivers.

2008 Indiana Department of Environmental Management 303(d) Combined Impaired Waters Summary <sup>22</sup>		
Waterbody Name/Segment	Status	Cause of Impairment
Buttermilk Creek (INB11G9_00)	Listed	Sulfates
		Total Dissolved Solids (TDS)
Maria Creek Headwaters (INB11K1_01)	Listed	Dissolved Oxygen
		E. coli
		Impaired Biotic Communities
Black Creek - Brewer Ditch (INW0262_00)	Listed	Sulfates
		Impaired Biotic Communities
		Total Dissolved Solids (TDS)
Singer Ditch (upper) - Hill Ditch (INW0266_00)	Listed	E. coli
Black Creek - Singer Ditch - White River Oxbows Tributaries (INW0267_00)	Listed	E. coli
Busseron Creek - Tanyard Branch (INB11GD_00)	Listed	Sulfates
		Total Dissolved Solids (TDS)

2010 Draft Indiana Department of Environmental Management 303(d) Combined Impaired Waters Summary <sup>22</sup>		
Waterbody Name/Segment	Status	Cause of Impairment
Buttermilk Creek (INB11G9_00, 01, 02, 03)	Listed	Sulfates
Maria Creek Headwaters (INB11K1_01)	Listed	Dissolved Oxygen
		E. coli
		Impaired Biotic Communities
Black Creek - Brewer Ditch (INW0262_00)	Listed	Sulfates*
		Impaired Biotic Communities
Singer Ditch (upper) - Hill Ditch (INW0266_00)	Listed	E. coli
Black Creek - Singer Ditch - White River Oxbows Tributaries (INW0267_00)	Listed	E. coli
Busseron Creek - Tanyard Branch (INB11GD_00)	Listed	Sulfates

\*Data available from the Indiana Department of Environmental Management does not support that sulfate is cause of impairment.

Numerous substances can cause water pollution in the project area. These can include sediment from the erosion of exposed earth, nutrients from soil amendments, oxygen-demanding wastes from septic systems, acidic ions from improperly handled coal waste, toxic metals from illegal dumping, biological waste from septic systems and animal operations, and abandoned mine lands (AML) sites. Sources of pollutions can be divided into two categories: point source pollution and non-point pollution. Point source pollution is typically discharged from a pipe while non-point pollution is more widespread and cannot be pinpointed to one location. This pollution is discharged primarily in response to precipitation events.

Within the Middle Wabash-Busseron and Lower White watersheds, there are several known and regulated point sources of pollution. Dischargers must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the State of Indiana. The primary pollutants being released through a pipe, ditch, or other well defined points can be oxygen demanding wastes, nutrients, sediment, and possible toxic materials. As of April 10, 2009, the following table tabulates the number of NPDES permits within the affected watersheds and notes how many are major. Major dischargers are facilities that discharge over one million gallons per day or sustain wastewater from a population greater than 10,000. There are no major dischargers within the smaller 14-digit watersheds of the permit area.

Active NPDES Permits <sup>9</sup>		
Watershed	Total NPDES Permits	Major Discharge Permits
Buttermilk Creek	1	0
Middle Fork Creek (Sullivan)	0	0
Maria Creek Headwaters	0	0
White River - Pollard Ditch	1	0
Black Creek - Brewer Ditch	0	0
Middle Wabash - Busseron	35	10
Lower White	58	9

Within the smaller 14-digit watersheds of the permit area, as well as the Middle Wabash-Busseron and Lower White watersheds, there are may be failing septic systems or septic systems that have been connected into field drainage tiles. Due to this area being rural in nature, homes within the area are almost entirely on septic systems. Failing septic systems are known sources of E. coli impairments in water bodies. Due to forested areas being concentrated along the stream corridors, wildlife can also cause impairments in water bodies. Many animals such as deer, geese, ducks, raccoons, and turkeys spend time in or around water bodies contributing to their potential impairment. There are also smaller livestock operations within these watersheds that are not regulated due to their small size under the confined animal feeding operation regulations. These operations may have an impact on the water quality.

Agricultural activities provide the majority of the non-point pollution within the affected watersheds. Land clearing and conventional tilling of the land makes soil susceptible to erosion. Soil amendments such as pesticides and fertilizers can also be washed from the fields. Conservation tillage along with vegetated buffer strips along the streams and ditches would greatly minimize sediment and nutrient loads into the streams. Runoff from urban and residential land use is not a large source of pollution for the immediate receiving waters of this permit as it is in largely a rural community. Runoff from impervious features such as roofs and roadways increases discharge to the receiving streams rather than allowing the rainfall event to soak into the ground. This increased discharge can accelerate stream bank erosion and sediment transport.

The Bear Run Project has an active NPDES permit that authorizes mine-related discharges. These discharges occur from sediment basins which are located as close to the disturbance area as practicable and are monitored for pH, suspended solids, settleable solids and iron, thereby preserving downstream habitats. All disturbed areas would drain to a sedimentation pond to ensure acceptable quality of any drainage from the site. Prior to initiating land clearing appropriate sedimentation ponds and upstream collection channels will be constructed. Sedimentation pond spillways will be protected to minimize soil erosion by utilizing riprap or quickly germinating vegetation. Upon completion of construction of the sedimentation ponds, affected areas would be graded to drain to the sediment. All discharges from the sedimentation ponds would be required to meet the numerical effluent limits for suspended solids, per the NPDES permit. Reclamation practices at coal mines such as the use of sediment basins and terraces and have proven successful in reducing erosion and sediment loss. Best Management Practices for erosion and sediment control will be implemented and no negative impacts to the waters outside of the area planned for mining should occur. Riparian buffers will be reestablished adjacent to the stream mitigation along and with conservation tillage practices will be recommended to tenant farmers.

Any effects of the Bear Run Project on surface water quality should be temporary and minimal. Effluent from NPDES discharge points is proposed to meet all applicable state and Federal standards and is compatible with that in the receiving stream. Adherence to these limits will ensure that adverse impacts will not occur to the surface water quality of the receiving stream as a result of the proposed operations.

#### Biological Quality

Biological quality was evaluated with assessments of regional watersheds by the Indiana Department of Environmental Management's Biological Studies Section and project specific streams by Wetland Services, Inc.

The Indiana Department of Environmental Management's Biological Studies Section conducts ecological assessments of Indiana surface waters. Surveys conducted assess aquatic habitat quality, fish community health, and invertebrate community health. The following summarizes assessments that were conducted within the

Middle Wabash - Busseron (Indiana) watershed (HUC 05120111) and the Lower White watershed (HUC 05120202). IDEM monitoring locations are shown in Figures 1-5.

IDEM uses the Qualitative Habitat Evaluation Index (QHEI) to assess habitat quality of a stream in conjunction with macroinvertebrate and fish sampling. The QHEI uses six metrics to score the habitat quality: 1) substrate, 2) instream cover, 3) channel morphology, 4) riparian zone and bank erosion, 5) pool/glide and riffle/run quality, and 6) gradient. IDEM has determined that a QHEI total score of <51 is poor for habitat. Results from IDEM's QHEI assessments are shown in Tables 1 and 2. The total scores ranged from 93 to 26 with an average score of 60 and a standard deviation of 13. This shows that the majority of sites are of relatively poor habitat quality with little variability across the watersheds. Average QHEI scores at sites located downstream of the Bear Run permit area included Maria Creek at 49 and 56.5 (two sites), Busseron Creek at 65, Marsh Creek at 38, and Brewer Ditch at 29.

Habitat quality is generally a reflection of the surrounding land uses and management practices. In the Middle Wabash - Busseron watershed, land use is predominantly agricultural vegetation (70 percent) followed by forest vegetation (19 percent), wetland vegetation and open water (7 percent), and urban (4 percent). In the Lower White watershed, land use is predominantly agricultural vegetation (49 percent), followed by forest vegetation (41 percent), urban (8 percent), and wetland vegetation and open water (2 percent). Numerous land management techniques occurred in the past that still impact the stream habitat quality today including, but not limited to, channelization of streams and removal of riparian buffers. These past management practices may be partially responsible for the low QHEI results.

For macroinvertebrate assessments, IDEM has developed a macroinvertebrate Index of Biotic Integrity (mIBI). Sampling methods follow the USEPA Rapid Bioassessment Protocols (RBP). In Indiana, a stream segment is non-supporting for aquatic life and considered "poor" or "very poor" use when the monitored macroinvertebrate community receives a mIBI score for multi-habitat samples of less than 36, for kick samples of less than 2.2, or for Hester/Dendy samples of less than 1.4. Results from IDEM's macroinvertebrate sampling are shown in Tables 3 and 4. Results show that of the 91 assessments, 17 show poor macroinvertebrate health and are non-supporting of the aquatic life use classification. Another 9 showed borderline results, with the mIBI result exactly equal to the threshold. Four of these sites, Busseron Creek, Marsh Creek, and Maria Creek (2 sites) are located downstream of the Bear Run permit area. These sites received scores as follows: Busseron Creek 3.4 (kick), Marsh Creek 2.6 and 4.8 (kick), Maria Creek 4.8 (kick), and Maria Creek 28 (multi-habitat).

When assessing fish community quality, IDEM uses the Index of Biotic Integrity (IBI) to define fish community characteristics. The IBI is based on 12 metrics that assess the community's species and trophic composition and fish condition and health. For IDEM's purposes of identifying impaired waters, an IBI score of less than 35 is considered non-supporting for aquatic life use. Results of IDEM's fish assessments are shown in Tables 5 and 6. Of the 54 assessments, 17 sites show poor fish community health and are non-supporting of the aquatic life use classification. Two of these sites, Maria Creek and Brewer Ditch, are located downstream of the Bear Run permit area. These streams received scores of 30 and 16, respectively, signifying poor fish community health.

The majority of IDEM's sampling results show poor quality habitat streams and as a result poor aquatic life community health. During active mining, impacts to these watersheds would be minimized through regulatory mechanisms. The NPDES permitting program regulates water quality of effluent to ensure protection of applicable uses of the receiving streams, including aquatic life. All runoff from areas affected by mining flows through NPDES permitted sediment basins prior to discharge. Following active mining, the affected streams and wetlands will be mitigated to a higher quality than what currently exists. Mitigated streams are typically sinuous with instream habitat structures, riffle/pool complexes, rock beds, and adequate riparian buffers. The mitigated streams and wetlands will provide high quality habitat for aquatic life, inevitably improving the fish and macroinvertebrate community health in the area.<sup>24</sup>